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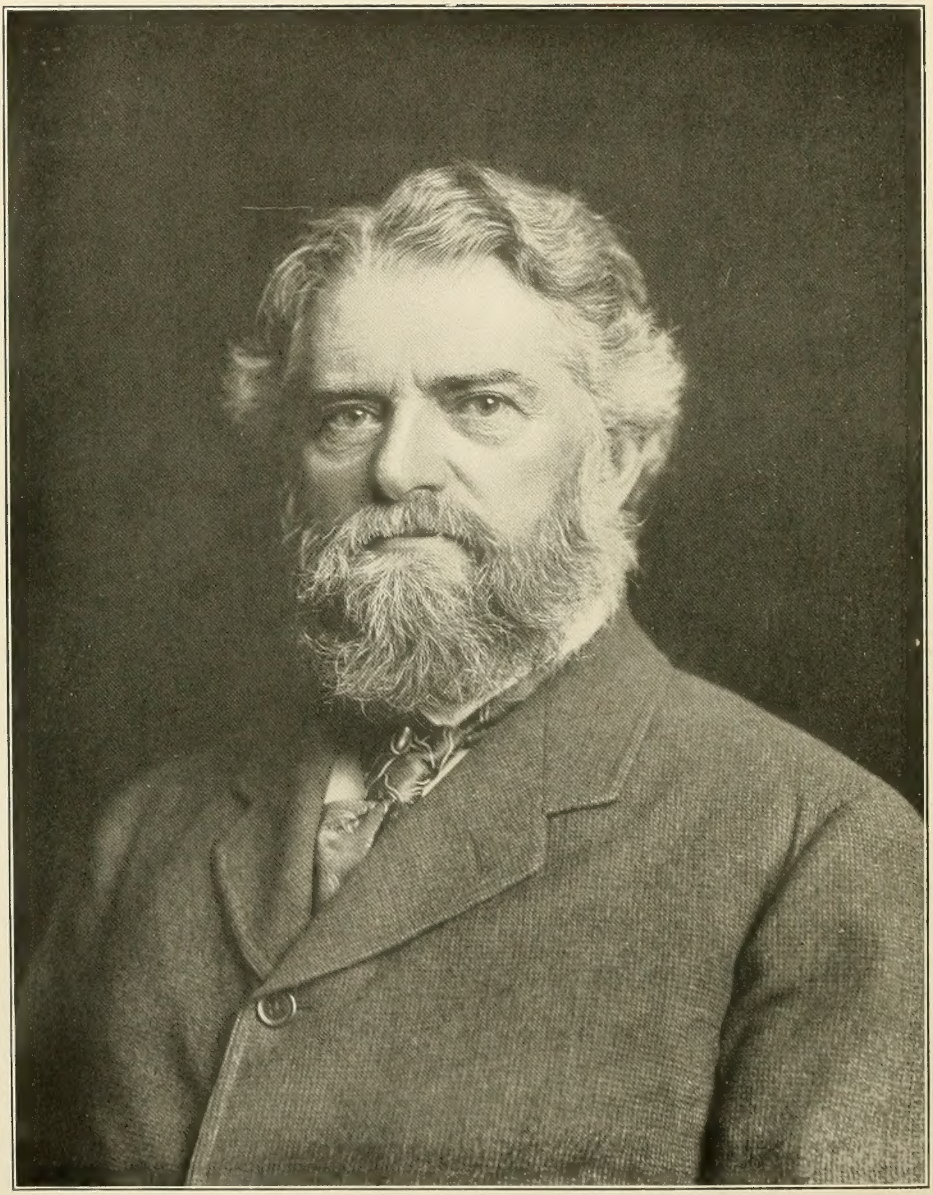

SIMON NEWCOMB

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american astronomical society

PUBLICATIONS

OF THE

Astronomical and Astrophysical Society of America

VOL. I

Organization, Membership, and
Abstracts of Papers
1897-1909

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1910

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Meetings of the Society are held annually at such times and places as may be selected by the Council.

COMMITTEE ON PUBLICATION

FOR THIS VOLUME:

Edward C. Pickering, William J. Hussey.

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Astronomical and Astrophysical Society of America

ORGANIZATION AND MEMBERSHIP.

The establishment of the Astronomical and Astrophysical Society of America may be traced directly to the first conference of astronomers and astrophysicists, held in connection with the dedication of the Yerkes Observatory. This was made an important occasion, and was attended by many distinguished persons, not only from Chicago and vicinity, but also from various parts of the country and abroad. The formal presentation of the Observatory to the Trustees of the University of Chicago and its acceptance by them took place within the great dome on October 21, 1897, in the presence of a large assemblage, with appropriate addresses by Mr. Charles T. Yerkes, the donor; Mr. Martin A. Ryerson, the Chairman of the Board of Trustees; by Dr. William Rainey Harper, President of the University; and by Dr. George E. Hale, Director of the Observatory. The dedicatory address was given at this time by Professor James E. Keeler, on "The Importance of Astrophysical Research and the Relation of Astrophysics to the other Physical Sciences." The exercises were continued on the following day in Chicago, when, in the afternoon, Professor Simon Newcomb delivered an address in Kent Theater at the University on "Aspects of American Astronomy." That evening, in conclusion, Mr. Yerkes provided a banquet for the visiting scientists.

During the three days preceding the dedication, October 18-20, a series of meetings were held at the Observatory for the reading and discussion of papers on astronomical and astrophysical subjects. The program had been carefully planned by Professor Hale, and included not only the presentation of papers but also numerous demonstrations of the work of the Observatory, a reception to those in attendance, and an excursion upon Lake Geneva.

This conference was successful in bringing together a large number of astronomers and astrophysicists, whose contributions in the form of papers and discussions rendered the proceedings of great value. So much was accomplished that it was felt desirable to repeat the conference in the following summer, with a view to its continuance in future years. A preliminary inquiry, directed to those who had been present at the first conference, and to others who were considered likely to attend a second one, brought a large number of satisfactory replies. The writers were practically unanimous in favor of continuing the meetings and definite acceptances were so numerous as to ensure the success of a second conference at the Yerkes Observatory. It was found, however, that its geographical position would prevent many persons in the eastern states from coming. This difficulty was removed when Professor Pickering extended an invitation to those interested to hold the second conference at the Harvard College Observatory, beginning on Thursday, August 18, 1898, and continuing until the following Saturday. This plan was especially advantageous, since the Fiftieth Anniversary Meeting* of the American Association for the Advancement of Science was to open in Boston on the following Monday, August 21, thus enabling those who desired to do so to remain for that interesting event.

The selection of the Harvard College Observatory as the place for the second conference doubtless had much to do with the highly successful outcome of the gathering. The numerous instruments, many of them operated by automatic devices, together with an unrivalled collection of celestial photographs, afforded visitors opportunities for study not to be found elsewhere. The meetings were held in the drawing room of the Director's residence, which was most hospitably thrown open for the occasion. At the conclusion of the first morning's session, the members of the conference were entertained at luncheon by Professor and Mrs. Pickering, and on the second day similar entertainment was provided at the Faculty Room by the President and Fellows of Harvard University. On the third day, after the adjournment of the regular sessions, a large party visited the Blue Hill Meteorological Observatory at the invitation of the proprietor, Mr. A. Lawrence Rotch. Ample opportunity was afforded between the sessions for the inspection of the laboratories and museums of Harvard University, while the members of the Observatory staff were always ready to assist visitors in their examination of the instruments and photographs so bountifully displayed.

At the session on Friday morning, which was devoted to matters of general interest, it was resolved by unanimous vote that the annual conferences should be continued, either in their existing form or under the auspices of a permanent society, and a committee was appointed to consider the manner in which they could best be conducted. This committee consisted of Messrs. George E. Hale, Chairman, Simon Newcomb, Edward C. Pickering, Edward W. Morley, and George C. Comstock, Secretary. In offering their report at the next session of the conference, the committee recommended the formation of a permanent society and presented a first draft of a constitution. The conference at once accepted the substance of the proposed plan, and, following the recommendation of the committee, called a special meeting for the purpose of effecting a preliminary organization by those who had previously signed a statement signifying their wish to become charter members of the society. The meeting was duly held, on August 23, 1898, at the Massachusetts Institute of Technology in the City of Boston. After a brief discussion, the plan of organization was referred to the same committee, who were given power to add four to their number and authority to act *ad interim* as the Executive Council of the new Society. The duties of the Committee were to include the drafting of a constitution, the election of members to the Society, the making of arrangements for the next meeting, and other business of a similar nature. The Committee was enlarged by the addition of Messrs. S. P. Langley, Lewis Boss, A. A. Michelson, and J. S. Ames.

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*Forty-seventh Annual Meeting.

The Executive Council met next at the Smithsonian Institution in Washington, on February 18, 1899, with Messrs. Comstock, Hale, Langley, Morley and Newcomb in attendance. Professor Newcomb presided and the day was spent in considering the plans for the Society and in putting the Constitution and By-Laws in shape for presentation to its members. The Council also accepted the invitation of Professor Hale to hold the third Conference at the Yerkes Observatory, in September, 1899. At the second session of this Conference, which is now known as the First Meeting of the Society, the Constitution and By-Laws, substantially in the form presented by the Committee, and as printed below, were unanimously adopted, and in accordance with their provisions the formal organization of the Society was completed on the last day of the Conference, September 8, 1899, by the election of officers as follows:

President	Simon Newcomb.
First Vice-President	Charles A. Young.
Second Vice-President	George E. Hale.
Secretary	George C. Comstock.
Treasurer	Charles L. Doolittle.
Councilors for two years	Edward C. Pickering and James E. Keeler.
Councilors for one year	Ormond Stone and Edward W. Morley.

The majority of those first elected to office have remained continuously in the Council of the Society. Professor Newcomb was first made President during his absence abroad, and year after year he was re-elected, until 1905, when, at his earnest request, he was relieved from the duties of office. He was then made a life member of the Council, and, as long as he lived, maintained the deepest interest in the Society. He considered its work of great importance to the progress of science on this side of the Atlantic. In his letter declining further election as President, he said: "Through the Society we share the advantages enjoyed by the promoters of other branches of pure and applied science, which flow from mutual help, counsel, criticism and friendly interest. I therefore earnestly hope that the Society will increase in numbers and that its meetings will be of yet greater interest and advantage to all the members who are able to attend them."

The members of the Society at the time of its organization numbered one hundred and thirteen, as follows:

C. G. Abbot
W. S. Adams
J. S. Ames
Louis W. Austin
Solon I. Bailey
E. E. Barnard
Louis A. Bauer
N. E. Bennett
Lewis Boss
S. H. Brackett
Martin Brennan
S. J. Brown
Frederick L. Chase
S. J. Coffin
W. H. Collins
H. R. Colson
George C. Comstock
Henry Crew
Charles R. Cross
Herman S. Davis
Elizabeth Dobbin
Charles L. Doolittle
Eric Doolittle
D. A. Drew
H. W. DuBois
J. A. Dunne
A. St. C. Dunstan
John R. Eastman
W. S. Eichelberger
William L. Elkin
Ferdinand Ellerman
Henry Brown Evans
Ervin S. Ferry
Williamina P. Fleming
Albert S. Flint
Edgar Frisby
Lucy Ames Frost
Edwin B. Frost
Royal H. Frost
Caroline E. Furness
E. F. Gill
H. M. Goodwin
Ida Griffiths
John G. Hagen
George E. Hale
Asaph Hall, Jr.
William Harkness
J. N. Hart
G. W. Hough
C. S. Howe
W. J. Humphreys
Harold Jacoby
James E. Keeler
Edward S. King
Lawrence LaFarge
S. P. Langley

Kurt Laves
Henry C. Lord
Carl A. C. Lundin
A. C. Lunn
Alexander MacFarlane
Antonia C. Maury
A. A. Michelson
Dayton C. Miller
E. Miller
Edward W. Morley
F. R. Moulton
G. W. Myers
Simon Newcomb
E F. Nichols
H. M. Parkhurst
J. A. Parkhurst
Henry M. Paul
B. O. Peirce
Charles D. Perrine
O. L. Petitdidier
Edward C. Pickering
William H. Pickering
Henry S. Pritchett
A. W. Quimby
Stanley C. Reese
M. E. Rice
G. W. Ritchey
C. H. Rockwell
Clement E. Rood
Jonathan T. Rorer
A. Lawrence Rotch
John C. Shedd
Aaron N. Skinner
Frederick Slocum
Charles M. Smith
Benjamin W. Snow
Monroe B. Snyder
Mabel C. Stevens
John N. Stockwell
Ormond Stone
John Tatlock, Jr.
David P. Todd
Winslow Upton
J. M. VanVleck
Frank W. Very
F. L. O. Wadsworth
Worcester R. Warner
O. C. Wendell
Sarah F. Whiting
Frank P. Whitman
Mary W. Whitney
Elva G. Wolffe
Robert W. Wood
Ida Woods
Robert S. Woodward
P S. Yendell
Charles A. Young

Since the organization of the Society one hundred and eighty additional members have been elected by the Council. The names and dates of election are as follows:

Cleveland Abbe	1900
Robert Grant Aitken	1901
Sebastian Albrecht	1902
Leah Brown Allen	1910
A. Thomas G. Apple	1910
Peter Archer	1910
Oskar Backlund	1910
George P. Bacon	1909
Robert Horace Baker	1904
Storrs B. Barrett	1908
Samuel G. Barton	1908
John R. Benton	1902
Frank H. Bigelow	1901
Harriet W. Bigelow	1906
Benjamin Boss	1905
Frank P. Brackett	1902
John A. Brashear	1902
Ernest W. Brown	1904
Louise Brown	1910
Robert E. Bruce	1910
Daniel Buchanan	1909
Alfred E. Burton	1901
Mary E. Byrd	1901
Mary Ross Calvert	1909
William W. Campbell	1900
Annie Jessup Cannon	1904
William T. Carrigan	1908
A. J. Champreux	1910

Seth C. Chandler	1901
C. A. Chant	1906
W. A. Cogshall	1905
Judson B. Coit	1902
Wilbur A. Coit	1910
Russell Tracy Crawford	1901
Charles W. Crockett	1900
Heber D. Curtis	1903
Ralph H. Curtiss	1903
W. Walter Dinwiddie	1902
A. E. Douglass	1910
Mrs. Henry Draper	1900
Raymond S. Dugan	1904
J. C. Duncan	1910
F. W. Dyson	1910
Sturla Einarsson	1910
Herman A. Fischer	1909
Frederick E. Fowle, Jr.	1900
Philip Fox	1908
W. S. Franklin	1903
Charles W. Frederick	1902
Matt Frederickson	1909
William Gaertner	1909
Norman E. Gilbert	1905
Charles Grosjean	1910
Stephen M. Hadley	1902
James P. Hall	1900
Asaph Hall	1900
W. A. Hamilton	1909
John C. Hammond	1902
Margaret Harwood	1910
W. E. Harper	1908
Flora E. Harpham	1900
Ellen Hayes	1910
John F. Hayford	1902
Henry B. Hedrick	1904
Josef v. Hepperger	1910
George A. Hill	1900
George W. Hill	1900
S. V. Hoffman	1900
Mary Murray Hopkins	1909
Herbert A. Howe	1900
L. G. Hoxton	1909
Charles John Hudson	1910
Gordon F. Hull	1900
William J. Hussey	1901
George S. Isham	1901
L. E. Jewell	1902
William R. Jewell, Jr.	1909
Frank C. Jordan	1909
Edith Kast	1904
Norton A. Kent	1903
J. E. Kershner	1900
Theo. I. King	1901
W. F. King	1908
Eleanor A. Lamson	1909
Edgar L. Larkin	1903
Jennie B. Lasby	1910
Thomas A. Lawes	1909
George K. Lawton	1900
F. P. Leavenworth	1902
Henrietta Swan Leavitt	1904
Oliver Justin Lee	1909
Armin O. Leuschner	1901
George A. Lindsay	1909
Frank B. Littell	1901
Frank H. Loud	1904
Edgar O. Lovett	1902
Percival Lowell	1900
C. A. Robert Lundin, Jr.	1910
James A. Lyon, Jr.	1900
Clement H. McLeod	1900
W. D. MacMillan	1909
James D. Maddrill	1903
Edmund S. Manson, Jr.	1909
John E. Mellish	1909
Charles E. Mendenhall	1901
W. O Mendenhall	1909
Paul W. Merrill	1909
Joel H. Metcalf	1908
William Ferdinand Meyer	1910
Willis I. Milham	1910
John A. Miller	1903
S. Alfred Mitchell	1900
Walter M. Mitchell	1908
Joseph H. Moore	1903
D. W. Morehouse	1909
Herbert R. Morgan	1902
Perley Gilman Nutting	1910
C. P. Olivier	1909
William W. Payne	1901
Henry A. Peck	1900
George Henry Peters	1900
O. L. Petitdidier	1909

Anton Petrajtis	1909
J. S. Plaskett	1906
Charles Lane Poor	1901
John M. Poor	1900
Jermain G. Porter	1905
Charles A. Post	1900
R. W. Prentiss	1902
Mary Proctor	1910
E. E. Read	1900
Frank W. Reed	1909
Taylor Reed	1900
J. K. Rees	1900
Herbert M. Reese	1901
Herbert L. Rice	1902
E. D. Roe, Jr.	1906
Frank E. Ross	1901
Henry Norris Russell	1900
R. F. Sanford	1910
Charles E. St. John	1909
Frank Schlesinger	1905
Lewis G. Schultz	1905
Karl Schwarzschild	1910
Frederick H. Seares	1902
Garrett P. Serviss	1900
T. McN. Simpson, Jr.	1909
Edwin L. Smith	1901
Elliott Smith	1903
Harrison W. Smith	1901
Joel Stebbins	1900
Harlan T. Stetson	1909
DeLisle Stewart	1908
S. W. Stratton	1902
Helen M. Swartz	1904
G. D. Swezey	1900
Stephen D. Thaw	1909
Elihu Thomson	1910
Edgar D. Tillyer	1909
Otto H. Tittman	1902
Sidney D. Townley	1900
Charles C. Trowbridge	1909
Richard H. Tucker	1900
Arthur B. Turner	1904
H. H. Turner	1910
Milton Updegraff	1901
Frank D. Urie	1909
Charles E. Van Orstrand	1909
Laenas G. Weld	1903
Percy F. Whisler	1910
Ida W. Whiteside	1905
Mrs. John C. Whitin	1909
Robert Wheeler Willson	1909
Delonza T. Wilson	1903
Herbert C. Wilson	1901
R. E. Wilson	1909
Walter L. Wright, Jr.	1901
William H. Wright	1901
Anne S. Young	1902
Everett I. Yowell	1902

The Society has continued to meet annually since its organization, and, as shown by the above lists, the number of members has more than doubled. Accounts of the meetings, with abstracts of the papers presented, have been published from year to year, either in the *Astrophysical Journal* or in *Science*. These accounts have been prepared by editors appointed by the Council, and in succession the following persons have served in this capacity: Edwin B. Frost, George C. Comstock, W. S. Eichelberger, Frank B. Littell, Harold Jacoby, F. H. Seares, and Frank Schlesinger.

At the tenth annual meeting, held at the Yerkes Observatory in August 1909, the Society authorized the publication of a volume which should contain a sketch of its organization, list of members, accounts of the various meetings, and so far as they are available, abstracts of the papers which have been presented to it. This book is the result of that authorization. In its preparation I have used freely the printed accounts of the various meetings contained in the periodicals mentioned and have supplemented the information so obtained by that found in papers belonging to the Secretary's records.

William J. Hussey,
Secretary.

Ann Arbor, Michigan,
September 15, 1910.

CONSTITUTION

Article I—Name and Purpose.

1. This association shall be called The Astronomical and Astrophysical Society of America.

2. The purpose of this Society is the advancement of astronomy, astrophysics, and related branches of physics.

Article II—Membership.

1. Those persons whose names were signed on or before September 15, 1899, to the annexed statement of desire to form such an association shall constitute the charter members of this Society. Other persons may be elected to membership in the Society by the Council hereinafter provided.

2. The Council shall prepare and publish in the form of a by-law uniform rules for the government of such elections.

Article III—Officers.

1. The officers of the Society shall consist of a President, two Vice-Presidents, a Secretary, and a Treasurer, who, in addition to the duties specifically assigned them by this constitution, shall discharge such other duties as are usually incident to their respective offices. These officers, together with four other members of the Society, shall constitute a Council to which shall be entrusted the management of all affairs of the Society not otherwise provided for. The President and Secretary of the Society shall serve respectively as chairman and secretary of the Council, and every officer of the Society shall be responsible to the Council and shall administer his office in accordance with its instructions.

2. The Council shall enact such by-laws as may be found needful and proper for administering the affairs of the Society, and may from time to time modify or repeal such by-laws.

3. The President, the Vice-Presidents and the Treasurer shall be elected annually in a manner to be prescribed by the Council and shall serve until their successors are duly elected and qualified. Two members of the Council shall be chosen at the first annual meeting of the Society to serve for a period of one year, and two members shall be chosen annually to serve for a period of two years or until their successors are duly elected and qualified. The term of office of

the Secretary shall be three years, or until his successor is duly elected and qualified.

ARTICLE IV—MEETINGS.

1. The Council shall determine the time and place of each meeting of the Society and shall provide for an annual meeting, at which officers shall be elected.

2. The Council shall have charge of the programme for each meeting.

3. At meetings of the Society, regularly called, twenty members shall constitute a quorum.

ARTICLE V—FINANCE.

1. The Council shall levy an annual assessment upon the members of the Society sufficient to provide the funds required by the Society for the ensuing year; provided that this assessment shall not exceed the sum of five dollars per member in any year.

2. If at any time there shall be required for the purpose of the Society a larger sum than can be obtained in accordance with Section 1 of this Article, the Council shall present at an annual meeting of the Society a statement of such need and of the circumstances attending it, and the Society shall thereupon determine by ballot a policy to be adopted in the matter.

3. No officer of the Society shall receive any compensation for services rendered to it, but the Council may by resolution direct the Treasurer to reimburse to any officer expenses necessarily incurred by him in the discharge of his official duty.

ARTICLE VI—AMENDMENTS.

1. This constitution may be amended by the affirmative votes of three-fourths of the members present at any annual meeting of the Society, but no amendment shall be voted upon unless a notice setting forth the nature of such proposed amendment shall have been forwarded to the several members of the Society at least one month before the meeting at which it is proposed to be voted upon.

2. It shall be the duty of the Secretary to forward such notices of a proposed amendment to this constitution, when so requested, in writing, by ten members of the Society.

FIRST AMENDMENT.

December 29, 1906. Every member of the Society who shall have served as President of the Society for a period of one year or more shall upon retiring from such office become thereby a member of the Council for life. The number of elective Councilors shall not be thereby diminished.

BY-LAWS

1. Election of Members.

Any person deemed capable of preparing an acceptable paper upon some subject of astronomy, astrophysics, or related branch of physics, may be elected by the Council to membership in the Society upon nomination by two or more members of the Society. At least once in each year the Council shall consider all such nominations and may request the opinion of persons not members of the Council with reference to the qualifications of the nominees. Blanks for such nominations to membership shall be furnished by the Secretary.

2. Election of Officers.

The Council shall provide for holding, upon the day preceding the last day of each annual meeting, a nominating ballot at which each member of the Society may deposit his ballot for each officer to be elected for the ensuing year. Members not in attendance at such annual meeting may send to the Secretary their ballots enclosed in a sealed envelope bearing the signature of the voter. The Vice-Presidents, or in their absence, tellers appointed by the chair, shall canvass the ballots thus cast and shall prepare and pesent to the Society a list showing the three persons who have received the largest number of votes for each office to be filled. In case of a plurality of names receiving the same number of votes in third place, all the names in such plurality shall be included in the list.

Upon the last day of each annual meeting, written ballots shall be cast by the individual members of the Society for filling each office about to become vacant, of which only those shall be counted which are cast for persons nominated in the lists prepared as above directed for the office in question or for some higher office.

The nominee receiving the greatest number of votes for any office shall be thereby elected and shall be notified of such election in writing, by the Secretary, within ten days thereafter. It shall be the duty of each person thus notified to file with the Secretary his written acceptance of such office and if such acceptance is not filed within sixty days after notification, the Council, by resolution, may declare such office vacant and may elect any member of the Society to fill it until the close of the next annual meeting.

3. TREASURER.

The Treasurer of the Society shall keep accounts showing all receipts and expenditures of moneys belonging to the Society and showing also the indebtedness to the Society of each member thereof on account of unpaid assessments. These accounts shall be submitted at each annual meeting to an auditing committee of not less than three members, to be appointed by the Council. The Secretary shall be ex-officio a member of this committee.

4. SECRETARY.

The Secretary shall be the purchasing officer of the Society, and the Treasurer shall be the disbursing officer, but the total amount expended by the Secretary and Treasurer without previous authority from the Council shall not exceed the sum of fifty dollars in any year.

5. UNPAID ASSESSMENTS.

The Treasurer shall report to the Council at each annual meeting a list of all members indebted to the Society on account of unpaid assessments.

6. ORDER OF BUSINESS

The following order of business is prescribed for meetings of the Council.

a. Call to order by the chair.
b. Reading of minutes of last meeting.
c. Announcements by the chair.
d. Announcements by the secretary.
e. Announcements or reports by other officers.
f. Unfinished business.
g. New business.
h. Miscellaneous.
i. Adjournment.

7. QUORUM OF COUNCIL.

At any regularly called meeting of the Council three members shall constitute a quorum. Any member or members of the Society may be invited by such quorum to represent in the Council, for the time being, absent members thereof.

RESOLUTIONS.

The following resolutions of a permanent character have been adopted by the Council and are printed here for information of the Society.

December 29, 1902.

Resolved: That titles of papers that have been presented to other societies for publication will not be placed upon the programme of the Astronomical and Astrophysical Society of America without special vote of the Council.

December 30, 1902.

Resolved: That the President and Secretary of the Society shall constitute an executive committee of the Council to act *ad interim* upon such minor matters affecting the Society as in their judgment do not call for submission to the entire Council.

December 30, 1902.

Resolved: That the President be *ex officio* the representative of the Society upon all formal occasions calling for such representation, with power of substitution in case he finds it inconvenient to act.

December 31, 1902.

Resolved: That titles of papers submitted to the Council after its second session at any regular meeting of the Society will not be placed upon the programme of that meeting.

August 21, 1909.

By vote of the Society, it was

Resolved: That the name America in the name of the Society be interpreted to include North and South America and adjacent islands.

OFFICERS

Edward C. Pickering, President.
George C. Comstock, First Vice-President.
William W. Campbell, Second Vice-President.
William J. Hussey, Secretary.
Charles L. Doolittle, Treasurer.

COUNCILORS

W. J. Humphreys,
W. S. Eichelberger.
Frank Schlesinger,
E. B. Frost.

LIST OF MEMBERS

Abbe, Cleveland, United States Weather Bureau, Washington, D.C.
Abbot, C. G., Smithsonian Institution, Washington, D. C.
Adams, W. S., Solar Observatory Office, Pasadena, Cal.
Aitken, Robert Grant, Lick Observatory, Mt. Hamilton, Cal.
Albrecht, Sebastian, Argentine National Observatory, Cordoba, Argentina.
Allen, Leah Brown, Wellesley College, Wellesley, Mass.
Ames, Joseph Sweetman, Johns Hopkins University, Baltimore, Md.
Apple, A. Thomas G., Daniel Scholl Observatory, Lancaster, Pa.
Archer, Peter, Georgetown University, Washington, D. C.
Bacon, George Preston, Wakefield, R. I.
Backlund, Oskar, Central Observatory Nicholas, Pulkowa, Russia.
Bailey, Solon I., Harvard College Observatory, Cambridge, Mass.
Baker, Robert Horace, Ladd Observatory, Providence, R. I.
Barnard, Edward Emerson, Yerkes Observatory, Williams Bay, Wis.
Barrett, Storrs B., Yerkes Observatory, Williams Bay, Wis.

Bauer, Louis A., Department of Terrestrial Magnetism, The Ontario, Washington, D. C.
Barton, Samuel G., Clarkson School of Technology, Potsdam, N. Y.
Bigelow, Frank H., Oficina Meteorologica, Buenos Aires, Argentina.
Bigelow, Harriet W., Smith College Observatory, Northampton, Mass.
Boss, Lewis, Dudley Observatory, Albany, N. Y.
Boss, Benjamin, Dudley Observatory, Albany, N. Y.
Brackett, Frank P., Pomona College, Claremont, Cal.
Brashear, John A., Allegheny, Pa.
Brennan, Martin, 6304 Minnesota Ave., St. Louis, Mo.
Brown, Ernest W., Yale University, New Haven, Conn.
Brown, Louise, Dana Hall School, Wellesley, Mass.
Bruce, Robert E., Boston University, 688 Boyleston St., Boston, Mass.
Buchanan, Daniel, University of Chicago, Chicago, Illinois.
Burton, Alfred Edgar, Massachusetts Institute of Technology, Boston, Mass.
Byrd, Mary E., R. R. 9, Box 77, Lawrence, Kan.
Calvert, Mary Ross, Yerkes Observatory, Williams Bay, Wis.
Campbell, William W., Lick Observatory, Mt. Hamilton, Cal.
Cannon, Annie J., Harvard College Observatory, Cambridge, Mass.
Carrigan, William T., Nautical Almanac Office, Washington, D.C.
Chandler, Seth C., 17 Cushing Road, Wellesley Hills, Mass.
Champreux, A. J., Students' Observatory, Berkeley, Cal.
Chant, C. A., The University, Toronto, Canada.
Chase, Frederick L., Yale Observatory, New Haven, Conn.
Cogshall, W. A., Kirkwood Observatory, Bloomington, Ind.
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Coit, Wilbur A., Acadia University, Wolfville, N. S.
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Wright, Walter L., Jr., Lincoln University, Chester County, Pa.
Wright, William Hammond, Lick Observatory, Mt. Hamilton, Cal.
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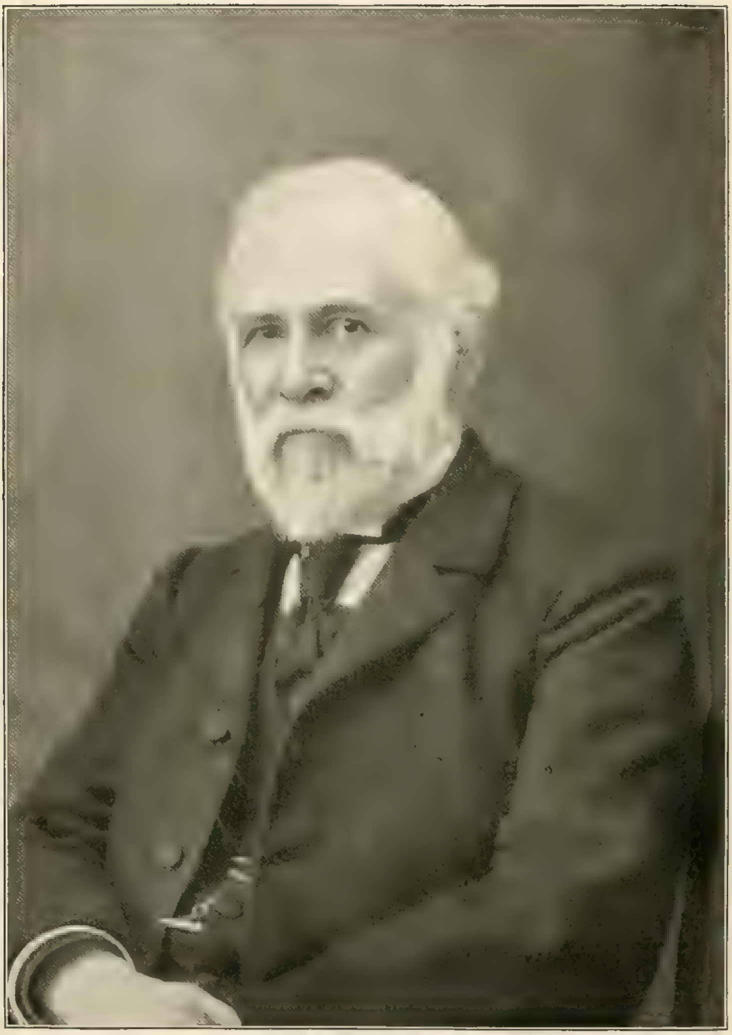

CHARLES A. YOUNG

PUBLICATIONS

OF THE

Astronomical and Astrophysical Society of America

FIRST CONFERENCE

The first Conference of Astronomers and Astrophysicists was held on Monday, Tuesday and Wednesday, October 18-20, 1897, in connection with the dedication of the Yerkes Observatory. The first session was devoted to the fourth annual meeting of the Board of Editors of the *Astrophysical Journal,* at which the visiting scientists were invited to be present.* At this time Professor Schuster's paper was read and discussed. At the succeeding sessions a large number of additional papers were presented, abstracts of which are given in the following pages. During the Conference ample opportunity was afforded for the inspection of the instruments and laboratories of the Observatory, where many interesting demonstrations were made. Thus, in the optical laboratory, Mr. Carl Lundin, of Alvan Clark & Sons, showed the method employed by his firm in testing telescopic objectives, and Mr. Ritchey demonstrated the operation of the large grinding machine carrying a five-foot disk of glass for a speculum. In the spectroscopic laboratory, Professor Wadsworth exhibited an interferometer designed for the measurement of wave-lengths in infra-red metallic spectra. Professor Crew showed his rotating metallic arc in the physical laboratory, and exhibited its spectrum with a large plane grating spectroscope. In the northeast dome Professor Lord exhibited the stellar spectroscope of the Emerson McMillin Observatory, attached to the twelve-inch equatorial. Both the instrument and optical shops were in operation, and various instruments were shown in process of construction.

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*At earlier meetings of this Board the desirability of an astronomical society had been discussed.

The forty-inch refractor was placed at the disposal of visitors each evening, but the cloudy state of the sky made it impossible to carry out the more delicate demonstrations which had been planned for this instrument. Nevertheless, it was possible to show a few double stars, nebulae, and clusters on Monday and Tuesday evenings.

A list of the astronomers, astrophysicists and physicists who took part in the Conference is given below. It should be added that M. Deslandres of the Paris Observatory, and Professor Schuster of Victoria University, Manchester, visited the Observatory with the intention of taking part in the exercises, but were unable to remain, owing to the postponement of the dedication.

E. E. Barnard
N. E. Bennett
John A. Brashear
William R. Brooks
S. W. Burnham
Hugh L. Callendar
E. Colbert
W. H. Collins
George C. Comstock
Henry Crew
Susan J. Cunningham
C. L. Doolittle
Ferdinand Ellerman
A. S. Flint
Edwin B. Frost
Caroline E. Furness
J. G. Hagen, S.J.
George E. Hale
Asaph Hall, Jr.
William Harkness
John T. Hedrick, S.J.
George W. Hough
G. F. Hull
W. J. Humphreys
Leslie H. Ingham
James E. Keeler
Kurt Laves
F. P. Leavenworth
H. C. Lord
Carl A. R. Lundin
C. H. McLeod
F. R. Moulton
E. Miller
G. W. Myers
Simon Newcomb
E. F. Nichols
John A Parkhurst
Henry M. Paul
W. W. Payne
E. C. Pickering
Charles Lane Poor
Henry S. Pritchett
A. W. Quimby
J. K. Rees
G. W. Ritchey
Charles H. Rockwell
Carl Runge
Frederick H. Seares
B. W. Snow
M. B. Snyder
C. D. Swezey
Milton Updegraff
Winslow Upton
J. M. VanVleck
Frank W. Very
F. L. O. Wadsworth
Mary W. Whitney

Many other well-known men of science, who were unable to take part in the Conference, were present at the dedicatory exercises.

ABSTRACTS OF PAPERS

The following synopses of the papers read at the astronomical and astrophysical conferences held at the Yerkes Observatory in connection with the dedication, have been prepared by the authors. In some cases only the title is given, on account of the author's desire to publish the complete paper in the *Astrophysical Journal* or elsewhere. The order of the papers is that in which they were read at the conferences.

ON THE MODE OF PRINTING MAPS OF SPECTRA AND TABLES OF WAVE-LENGTHS.

BY ARTHUR SCHUSTER.

My opinion with regard to the mode of printing maps of spectra and tables of wave-lengths agrees very nearly with that expressed by Professor Keeler in the *Astrophysical Journal* for August, 1897. It does not seem to me a matter of very great importance what decision is arrived at, but in whatever way the question is settled, all spectroscopists should conform to a uniform practice, even if it involves a little personal inconvenience at first. In making the few remarks which have occurred to me in connection with this matter I will take up the two questions separately.

1. *Mode of printing maps.*—What has determined the mode of printing maps? No doubt the particular construction of the spectroscopes employed by different observers. Fraunhofer must have had his spectroscope constructed so that he saw the red to the left, while Kirchhoff placed his prisms so that he saw the colors of the spectrum in the reverse direction. Many students first become acquainted with the appearance of the spectrum by means of the plates copied from Bunsen and Kirchhoff's first paper, in which the red is placed on the left; and hence they cannot picture to themselves the spectrum in any other way. Small spectroscopes are also, I believe, almost invariably made now so as to place the red on the left. The only reason for this that I can see, is that the observer while looking at the spectroscope ought to be able to handle the slit and flame or spark in front of the slit, and it is generally more convenient for him to use his right hand for the purpose. With single-prism spectroscopes this would render it necessary to construct them so that the red is on the left. But that is not an important matter, for physicists ought to be able to open or close the slit with the left hand.

It would be well, however, if the practice of placing the red is adhered to, to get the instrument makers to construct their spectroscopes accordingly, and architects to build their lecture rooms with the lantern on the right and the screen on the left. There may be some natural tendency in human beings which would favor one direction more than another. The way to find this out would be to place a small direct vision spectroscope in the hands of scientifically uneducated persons and to observe which way they hold it. My own experience would lead me to think that they would place the slit horizontal, so that the red would be either top or bottom; and there may even be something to be argued in favor of that practice. I only bring out these points to show that one might discuss the question indefinitely, and if one could start fresh from the beginning I do not know whether the balance of unimportant considerations would not turn in favor of having the red on the left. But Rowland's map is constructed with the red on the right, and this fact outweighs, in my opinion, all other considerations. In the majority of spectroscopic investigations of the present day Rowland's map has to be used, and it would be unbearable always to have to invert the direction. I should be sorry, therefore, if the present practice of the *Astrophysical Journal* were altered. Any one, of course, is at liberty to print a scale with inverted numbers at the bottom of a map, so that by turning the page around the smaller wave-lengths appear on the right. The question of series of lines I will discuss presently.

2. *Mode of printing tables.*—Here also most arguments which have been used in favor of one practice rather than another do not seem to me of very great weight. Wave-frequencies are quantities as important as wave-numbers, and if the latter succeed each other according to increasing figures, the former do so in the opposite way. But here the question of series has to be taken into consideration. It certainly seems more natural to print a series of lines which gradually become fainter so that the strongest should appear at the top. I would for this reason favor the reversal of the practice recommended by the Editorial Board. It has been argued that in printing maps the first and strongest lines of the series, and hence the red end, should be on the left, but I do not see that this is a matter of paramount importance. To my mind a series looks as well with the tail at the left as the other way around; with the present practice of the *Journal* no doubt the characteristic numbers of the lines in the series would increase from right to left, but I do not know that this is unnatural. A great many nations write from right to left and if one were to count a row of soldiers it would be as easy to begin at

one end as at the other. Those who are accustomed to consider a positive rotation as one opposite to that of the hands of a watch would, I believe, not find it unnatural when the first impulse is overcome to look at the series as beginning on the right hand side and tailing off on the left. Counting things from right to left seems to me to belong to a more advanced civilization than our present practice, which is the consequence of the apparent rotation of the sun around the earth. As soon as we realize that it is the earth that rotates, the left handed way of counting becomes the more natural one. Giving all due weight to the fact that Kayser and Runge's practice is to have the head of the series on the left, I believe that Rowland's map must settle the question as to the position of the red end, while in the matter of printing tables the increasing importance of Kayser and Runge's series renders it advisable to reconsider and probably reverse the present mode followed by the *Astrophysical Journal*.

While I am writing on these subjects I should like to mention two matters which might deserve the attention of the Board of Editors. One is the position of the decimal point in tables of wave-lengths or wave-numbers. In tables of the former, the practice of giving four figures in front of the decimal point is almost universally adopted, and should, in my opinion, be adhered to. But no general system is followed for wave-frequencies, and there seems to me to be a great advantage, chiefly as a help to the memory, if the number given should always be the number of wave-lengths in the centimeter. This would give five figures, the wave-number for green light, *e. g.*, being 20000.

The other question refers to the notation for the intensity of light. I do not know whether it will be possible at the present stage of science to come to a definite agreement, owing to the difficulty of using the same system for two such very different things as the solar spectrum and a spark spectrum. As a first step, however, I should like to urge that the higher intensities, whatever the scale, should always be denoted by the higher numbers. This is the practice adopted by the majority of physicists, and it is a matter of some inconvenience to compare together the results of two researches, in one of which the number one denotes the greatest intensity, while in the other the same number stands for the weakest line. A scale reaching from one to ten, using decimal points if necessary, might perhaps commend itself, but personally I am willing to adopt any practice which may be decided upon.

A general discussion followed the reading of Professor Schuster's paper. Professor Runge thought that the mode of printing tables and the mode of printing maps were two distinct questions. The occurrence of line series in the spectra of the elements had an important bearing on the first question. In a table beginning with short wave-lengths the uncertain lines are at the top, which is an inconvenience. On the other hand it is generally more convenient to have the numerical values in the table increase toward the bottom. A map can easily be turned end for end when it is necessary to compare it with another printed in the reverse direction. He did not think the subject an important one, was prepared to accept a decision in favor of either method, but thought harm was done by making a rule.

After further discussion the following resolution was adopted. *Resolved*: That the Editorial Board [of the *Astrophysical Journal*] adhere to the present practice of beginning tables with the short wave-lengths and of printing maps of the spectrum with the red end on the right, except in cases where a wish to the contrary is expressed by the author of any contributed paper.

Professor Schuster's suggestion regarding the position of decimal point in wave-numbers (the number given being the number of wave-lengths in the centimeter) was generally approved.

SPECTROSCOPIC NOTES.

BY SIR WILLIAM AND LADY HUGGINS.

This paper is printed in full in the *Astrophysical Journal* for November, 1897, (Vol. VI, p. 322). It contains accounts of the spectra of the stars in the trapezium of the Great Nebula of Orion, the spectra of the colored components of β Cygni, the ultra violet spectra of Vega and Arcturus, and the effect of density on the spectrum of calcium.

THE VARIABLE STAR WORK OF THE HARVARD OBSERVATORY.

BY E. C. PICKERING.

Professor E. C. Pickering described the studies of variable stars in progress at the Harvard College Observatory. Variables of long period have been observed for many years throughout their variations, at minimum as well as at maximum. A sequence of comparison stars is selected for each, the variable is compared by Argelander's method, and all the results reduced to a uniform scale, that of the meridian photometer. Short period variables are measured with the meridian photometer and with a polarizing photometer attached to the large telescope. Smooth light curves are thus obtained. The variable stars, SS Cygni and U Geminorum, form a peculiar class. The first of these stars was observed on about two hundred nights. Photometric observations of it were made extending over the whole of one night during its rapid increase. Many thousand observations have been made of the Algol stars, especially of U Cephei and W Delphini, the most accurate time keepers we have outside of the solar system.

STUDIES OF THE ELECTRIC ARC.

BY HENRY CREW.

Professor Crew described a method of studying the electric arc which had been devised by himself and Mr. O. H. Basquin.

By working the arc in a hood filled with a gas which has no chemical action upon the electrodes, they avoid any luminosity which might be called a 'chemical effect.'

By the use of a rapidly rotating occulting screen, they examine the arc immediately after the current has been cut off, and thus avoid any luminosity which might be called an 'electric effect.'

By the use of an alternating current, interrupted at the moment when the current-curve crosses the axis of X, they avoid "self-induction effects." In this manner the "purely thermal effects" are isolated.

It is found, however, that when the current is shut off different parts of the arc persist for different lengths of time. A spectroscopic examination of the different parts of the arc, and of arcs in different gases, is now in progress.

RESEARCH WORK AT THE WASHBURN OBSERVATORY. STELLAR PARALLAX, THE LUNAR ATMOSPHERE, THE OCULAR HELIOMETER.

BY GEORGE C. COMSTOCK.

The following summary of a paper presented to the astronomical conferences at the Yerkes Observatory is limited to two of the lines of research now in progress at the Washburn Observatory, one by Mr. A. S. Flint, being an extensive series of determinations of stellar parallax made with the Repsold meridian circle used as a transit instrument in accordance with the principles outlined by Kapteyn (*Leyden Annalen,* Bd. VIII), the other, of very much less extent, being an investigation by the Director of the Observatory of the limits of the density of an assumed lunar atmosphere whose existence is affirmed by many selenographers. In connection with the latter subject there was exhibited a Steinheil ocular heliometer obtained for use in this investigation, but which in its present form has proved unsatisfactory because certain conditions which theory indicates as essential in such an instrument were not observed in its construction.

A brief notice of this type of micrometer has been given by Gill (*Encyclopedia Britannica,* Article "Micrometer"), who condemns it as a failure; and a much more complete account by Von Konkoly (*Centralzeitung für Optik und Mechanik,* July, 1885), who assigns it the first rank among all known forms of double image micrometer. The writer of the present lines can not agree entirely with either of these critics, but regards the instrument as possessing good points which at present are rendered in great part nugatory by theoretical defects of construction, whose exposition lies beyond the scope of the present article.

The determination of the relative parallaxes through observed differences of right ascension contains nothing novel in principle, but the method does not appear to have been applied systematically and successfully save by Kapteyn and in the work here to be outlined. The observing program contained about a hundred stars chosen for the most part with reference to large proper motion and intended to comprise every star within one hundred and twenty degrees of the north pole whose proper motion exceeds one second of arc of a great circle. A certain number of these stars were, however, dropped from the list as being too faint for the modest aperture, 122 mm. of the instrument, and their places, together with other lacunae, were filled with other stars, usually interesting binaries or bright stars whose parallaxes elsewhere determined may serve as a control upon the general accuracy attained.

A normal observation consists in recording chronographically the times of transit over twenty-five threads of the star in question and two comparison stars so chosen that the star under investigation shall as nearly as may be bisect the arc joining them. It was in most cases feasible to select comparison stars which had not previously been employed for parallax determinations, but in some few cases, *e. g.,* Sirius and 61 Cygni, this was not done and could not be done without an undue sacrifice of other conditions. All of the stars observed were reduced to an approximate equality of brightness by the interposition of wire gauze screens immediately in front of the objective. An elevated track attached to the walls of the observing room supported these screens and permitted their convenient adjustment without allowing any part of the apparatus to come into contact with the telescope or its supports.

The parallax observations were commenced in October, 1893, and terminated in August, 1896, and the very laborious reductions are now sufficiently advanced to furnish the following results, each of which has been derived from a least squares solution involving in addition to the parallax a correction to the assumed relative star places and proper motion.

Star	Mag.	R. A.	Decl.	P. M.	Observed Parallax	Other Determinations
Gr. 34……	8.1	0^h 12^m	43° 25′	3″.8	+0″.44±0″.03	+0 .29 Auwers
η Cassiop…	3.8	0 42	57 15	2 .1	—0 .02 0 .04	0 .17 Schur
Ll. 7473 ….	8.5	3 56	35 1	2 .2	+0 .18 0 .06	
o^2 Eridani ..	4.7	4 10	— 7 49	4 .0	0 .31 0 .04	0 .17 Gill
a Tauri…..	1.0	4 29	16 18	0 .2	—0 .07 0 .06	0 .10 Elkin
W.B. V^h 592	8.7	5 26	— 3 41	2 .2	+0 .24 0 .04	
Sirius ……	—1.4	6 40	—16 34	1 .3	0 .31 0 .03	0 .38 Gill and Elkin
Ll. 30694 …	7.0	16 47	0 11	1 .6	0 .03 0 .04	
Ll. 31055 …	7.5	17 0	— 4 53	1 .5	0 .10 0 .03	
Σ 2398 *Pr*…	8.2	18 41	59 28	3 .1	0 .32 0 .05	0 .35 Lamp
61 Cygni *Pr*.	—	21 2	38 13	5 .2	0 .21 0 .03	0 .29 Mean of heliometer determinations
BD. 26°4721.	8.1	23 53	26 41	0 .1	0 .26 0 .04	

According to Neison every selenographer of consequence has recognized traces of a lunar atmosphere which could not be questioned were it not for the authority of Bessel, whose mathematical analysis of the conditions at the lunar surface has seemed to preclude the possibility of any considerable atmosphere. Neison, justly impugning the validity of this analysis has contended vigorously for the existence of an atmosphere, not indeed comparable in density with that of the earth, but sufficient to modify profoundly the physical conditions of the lunar surface, and some recent observers have sought to show the existence of a sensible refraction in the light of an object about to be occulted at the moon's limb.

It is generally conceded that such a refraction furnishes the most delicate test of the presence of an atmosphere, and although the relation between the physical characteristics of the supposed atmosphere (pressure, temperature, refractive index, law of diminishing temperature with increasing elevation) and the amount of the horizontal refraction is not an altogether simple one, no plausible relation can be assumed among these quantities which will reconcile the absence of refraction with the presence of any considerable atmosphere. Employing for the horizontal refraction and the law of diminishing temperatures the expressions of Laplace (*Mécanique Céleste,* Liv. X), and assuming the lunar atmosphere at standard temperature and pressure to have the same refractive index as air, I find as an approximate expression for the relation between the horizontal refraction, H, and the density ρ, of the lunar atmosphere in terms of the earth's atmosphere at sea level assumed as unity,

$$H = 484'' \rho(1 - \tau/546)$$

where τ represents the temperature at the moon's surface in degrees Centigrade.

It has been customary to assume upon the authority of the Greenwich occultations that H may be as great as 1″ or 2″, but this and all similar determinations appear fatally defective in that the result depends upon an assumed value of the moon's semidiameter, and I have sought to obtain a value of H free from this assumption by comparing with the filar micrometer of the forty-centimeter Clark equatorial the relative position of two stars as the moon approaches them; continuing the observations up to the moment of occultation of one of these stars. The distance from the moon's limb at which the apparent position of a star may be assumed unaffected by the lunar atmosphere depends upon the extent and density of the latter, and I have provisionally assumed as a result of the analysis leading to the relation between H and ρ above given that if the horizontal refraction does not exceed 1″ the effect of refraction will not in general be sensible until within two minutes of the occultation of the star.

The observations thus outlined are difficult of execution and stars suitably placed can not be found at all times, but practice and patience have in some measure overcome these difficulties and have furnished the following results for the amount, $2H$, by which a star at occultation is thrust away from the moon's limb. Each result is entirely independent of the others and is derived from an immersion at the moon's dark limb.

Date	2 H
1897, May 8	— 0″.3
8	+ 0 .0
9	+ 0 .3
9	+ 0 .2
9	— 0 .4
July 5	+ 0 .3
1897, July 5	— 0″.0
6	+ 0 .7
Oct. 3	— 0 .6
3	+ 0 .3
3	— 0 .8
3	— 0 .4

The mean of these results furnishes $H = -0''.03$, which differs from zero by less than its own probable error and which appears to me absolutely irreconcilable with any such value as $H = 1''$, although the number of results thus far obtained is not sufficient to furnish a definite value. The temperature at the dark limb of the moon is almost certainly below 0° C. and if we adopt this value for τ and take as the maximum permissible value of H, one-tenth of a second of arc, we shall have

$$\rho = 1/4840,$$

i. e., the maximum density of the permanent lunar atmosphere can not much exceed one-five-thousandth part of the density of the terrestrial atmosphere. If, as has been supposed by some astronomers, ice exists in considerable quantities at the surface of the moon, the change of temperature which accompanies the transition from night to day may produce a local and temporary atmosphere of aqueous vapor in certain parts of the moon's surface and it is to be noted that the foregoing observations furnish no information with regard to the presence or absence of such an atmosphere, since they were all made on the night side of the moon.

THE AIM OF THE YERKES OBSERVATORY.

BY GEORGE E. HALE.

This paper is printed in full in the *Astrophysical Journal* for November, 1897, Vol. VI, page 310.

SPECTRA OF STARS OF SECCHI'S THIRD TYPE

BY JAMES E. KEELER.

Professor Keeler showed on the screen a series of photographs of stellar spectra, mostly belonging to Secchi's third type. The slides were positive enlargements (ten diameters) of negatives made with the thirteen-inch refractor and star spectroscope of the Allegheny Observatory. Some of the spectra had been widened, by means of a movable camera, during the process of enlargement. They showed a great amount of detail which can be seen only with great difficulty by direct observation with the spectroscope. Five slides were required to show the spectrum of α Orionis from D to F.

In photographing the less refrangible regions of stellar spectra the chief difficulties arise from the unequal sensitiveness of orthochromatic plates to waves of different wave-lengths. The inequalities of density thus produced can be partially corrected in making the enlargements, by suitably graduating the exposure, but only a comparatively short range of spectrum can be well represented, and a number of different negatives are required to exhibit satisfactorily the whole region which the plate is capable of yielding. This region, however, often contains the most interesting and characteristic features of the spectrum.

The series of slides included the spectra of α Bootis, α Aurigae, α Tauri, α Orionis, α Scorpii, β Pegasi, and α Herculis, in which may be observed a transition from the second to the third type. In stars like α Orionis, the lines are essentially those of the solar spectrum, but the relative intensities are not the same, and the general aspect of the spectrum is quite different from the spectrum of the sun. The dark bands characteristic of third-type stars are well shown, though they are not resolved into lines. The separate lines are doubtless far beyond the resolving power of the instrument. These bands are not always terminated by strong metallic lines, and the appearance noted by early observers was probably due to insufficient optical power. The strong lines are mostly those of iron, apparently the low temperature lines. Their relatively greater strength in the star spectrum gives to some well-known solar groups (notably the *b* group) quite an unfamiliar aspect.

In α Herculis only a comparatively few of the strong metallic lines remain, while the bands are deep, and beautifully distinct. It is impossible to avoid the conclusion that the edges of the zones bordering on the dark bands are bright—much brighter, that is, than the average continuous spectrum—and that they are due to a real predominance of emission at the regions of the spectrum in which they occur. They are not merely the effect of absorption in adjoining regions. In the case of stars like α Orionis, of a less pure type, such a conclusion could not be safely drawn; yet the superior brightness of the spectrum at these places is obvious, and it can be traced even in second-type stars. May there not after all be bright regions in the solar spectrum, such as Draper supposed he had found in the places of the bright oxygen lines? And what is the relation between the dark bands in third-type stars and the bright zones which border on them?

THE STELLAR SPECTROGRAPHIC WORK OF THE EMERSON McMILLIN OBSERVATORY.

BY H. C. LORD.

In giving an account of my experience in the determination of motions in the line of sight, I would call attention to the great difficulty attending such work when the telescope employed is not corrected for the photographic portion of the spectrum. Numerous attempts were made in the fall of 1896, but the results were unsatisfactory and the special photographic corrector described in the *Astrophysical Journal,* Vol. VI, page 87, was ordered. This lens was not in place until June, 1897, and it was not until July that the adjustments were completed so that systematic work could be started. A reflecting slit was employed on account of its superior advantages in following. A 90° total reflecting prism was used to reflect the light from the comparison tube (hydrogen) on the slit. To adjust the comparison tube, the prisms were removed and a ground glass cap placed over the collimator objective; the entire apparatus was then moved until with a wide slit the collimator was shown to be full of light. The slit was then closed to the desired width, about the 1/1000 part of an inch. In this way a number of photographs were taken, which, though for the most part fairly satisfactory, showed some large discordances. A careful investigation of the instrument was then undertaken and the trouble finally located in the jaws of the slit, as it was found that as the slit was closed a shadow would creep across the collimator objective from one side, upon which no adjustment of the comparison tube produced the slightest effect.

The reflecting slit was then replaced by one of the ordinary form and the hydrogen tube placed directly in the cone of rays about seven inches in front of the slit, being turned out of the way during the exposure on the star. A number of photographs of the sky showed satisfactory agreement between the solar and artificial $H\gamma$, the maximum displacement being only 0.002 mm.

As this trouble was not discovered until late in August, but few results can be shown. Observations of γ Cygni, α Orionis, ϵ Pegasi, α Cassiopeiae, and Venus showed a constant positive difference from the Potsdam results on the stars and the computed velocity of Venus, It occurred to me that this might be due to a personal equation depending upon the direction of the plates under the miscroscope. In every case the red end had been placed on the right. The plates were remeasured with the red end on the left and a similar negative difference found, the mean of the two agreeing in almost every case with the Potsdam values. [For details see *Astrophysical Journal,* Vol. VI, p. 425].

ON THE APPLICATION OF DIFFRACTION PHENOMENA TO ASTRONOMICAL AND ASTROPHYSICAL MEASUREMENT.

BY F. L. O. WADSWORTH.

OXYGEN IN THE SUN.

BY C. RUNGE.

When I asked Professor Hale to put the subject of "Oxygen in the Sun" on the list for the conferences, I thought that we should have a discussion about it. I have learned, however, since then, that there is no more occasion for controversy, the former opponent now holding the same views. Let me therefore merely state how the evidence for the presence of oxygen in the sun now stands.

Professor Paschen and I discovered three strong lines in the utmost red part of that spectrum of oxygen which Schuster has called the compound line spectrum. It is produced in a vacuum tube by an induction current, without a Leyden jar and without a spark gap. On measuring these three lines we found that they coincided as nearly as we could make out, with three Fraunhofer lines that we found in the photographs made of this region by McClean and Higgs. The relative intensities were also the same, and this region of the spectrum not having many lines, there remains very little doubt that the coincidences are real. As to the proof of the presence of oxygen in the sun, it therefore only remained to be shown that these three lines are not produced in the earth's atmosphere, but that they are true solar lines.

When Paschen and I published this result, Mr. Jewell immediately took up the question. He examined the three Fraunhofer lines and came to the conclusion that they were atmospheric lines due to water vapor. Now this conclusion seemed to us very impossible indeed. We were ready to accept the view that the lines were due to atmospheric oxygen. But that they were due to water vapor would make the coincidences with the lines of the vacuum tube accidental, and three lines coinciding with lines of the same relative intensities in a region that contained so few lines, we could not believe to be a matter of chance. It was for this reason that I asked Professor Hale to let me have a discussion with Mr. Jewell at the conferences. Since his first observations, however, Mr. Jewell has not remained satisfied with the evidence, and he found that he had been misled by the want of a proper absorbent of the second order spectrum, that overlaps the first order spectrum, in which he was observing. The second order spectrum makes the Fraunhofer lines of the first order shine with violet light, and as the absorption of the violet light increases more rapidly with the sun's zenith distance than the absorption of red light, the first order lines seemed to increase in intensity. After he found the right sort of absorbent to cut off the second order he reported his observations, and the result is that he now withdraws his first conclusion. He finds that as far as his observations go the intensity of the three lines in question alters in the same way as true solar lines.

One might therefore almost say that the presence of oxygen in the sun is proved. Further evidence is gained from other lines. Paschen and I have shown that this red triplet is the first member of a principal series. We have found and measured the second member, a triplet of the same build but narrower—as narrow as the laws of the principal series requires it to be. This triplet also coincides with Fraunhofer lines, only that the middle line is hidden by an iron line. The other two lines, however, agree in position satisfactorily with Fraunhofer lines of unknown origin. These Fraunhofer lines are undoubtedly true solar lines, because on negatives made at Johns Hopkins University they show by their shifting the motion of the sun's limbs in the line of sight. This proof of the presence of oxygen in the sun I would regard as conclusive, if the lines in this part of the solar spectrum were not so closely set. The evidence of a real coincidence is inversely proportional to the density of the lines, and therefore it is much more convincing in the red part of the spectrum.

The proof would be conclusive if it were shown that the three red lines shift on the limbs of the sun, and we hope that some one better equipped for this kind of work than we are will take up the subject and will once for all settle the question.

EFFECT OF PRESSURE ON WAVE-LENGTH.

BY W. J. HUMPHREYS.

Increase of pressure about an electric arc increases the wave-lengths of the spectral lines so produced. This increase is very different for different elements and also for different series of lines of the same element, but the results of the investigation can be expressed fairly well by the simple equation:

$$\Delta\lambda = \alpha\beta\lambda\,(p - p_0),$$

where $\Delta\lambda$ is the increase in the wave-length λ of any given line produced by the increase of pressure $p - p_0$, β a constant for any series of lines and α a constant for any element. That is β for any series of a given element is the same as β for the corresponding series of any other element, while α for any series of a given element is the same as α for any other series of the same element. If we write β_0 for the principal series, β_1 for the first subordinate, and β_2 for the second subordinate, then, approximately, $\beta_0 : \beta_1 : \beta_2 = 1 : 2 : 4$.

By suitably choosing β, α may be replaced in most cases by $1/T$, where T is the absolute temperature of the melting point of the element in question, or by $e\sqrt{V}$, where e is the coefficient of linear expansion of the substance in the solid state and V the atomic volume, or finally, for either half of a Mendelejeff group, by $\sqrt[3]{W}$, where W is the atomic weight. From this last expression it is evident that α, and therefore $\Delta\lambda$, is a periodic function of atomic weight, and consequently the shifts of spectral lines may be compared directly with any other phenomenon which itself is a periodic function of the atomic weight.

THE LATITUDE WORK OF THE FLOWER OBSERVATORY.

BY C. L. DOOLITTLE.

I have been asked to give an informal account of the latitude work now in progress at the Flower Observatory, University of Pennsylvania. As to the method, nothing particularly new is involved. It is a continuation with a better instrument and under what are believed to be more favorable conditions of the work upon which I was engaged for a number of years at the Sayre Observatory, Bethlehem.

The instrument is a zenith telescope of four inches aperture and of forty-eight inches focal length, by Warner & Swasey.

We have introduced a feature not usually found in connection with this class of instruments, viz., two pairs of long focus collimators or mires, for the purpose of facilitating the adjustment in azimuth and collimation. The latter is somewhat troublesome with instruments of this type; the telescope not being symmetrically placed with respect to the vertical axis it is not possible to test the adjustment by simple reversal as with the transit instrument. It was a matter of time and patience to place these four mires in position and to adjust them perfectly, but they have proved to be very stable, and by their use the latitude instrument can readily be kept in such perfect adjustment that any star found on the observing list will come to the middle thread within a fraction of a second of its appointed time.

Four groups of stars have been employed for latitude: three groups contain ten pairs, and one group nine. Elsewhere in some cases the number of pairs in a group has in some cases been limited to six or seven; possibly seven pairs will give results nearly as good as ten. However, when the instrument has been adjusted and six or seven pairs observed it involves but little additional trouble to observe two or three more.

It is an easy matter to state the condition to which an ideal star list should conform, but like other ideals this one can not be realized in practice. Although much time has been expended upon the present list it falls short of perfection in a number of important particulars. In several cases the choice lay between the admission of long gaps in the series or the filling of these gaps with pairs which were objectionable in one way or another. As a matter of fact, in so far as can be discovered from internal evidence, these less desirable pairs appear to give nearly as good results as those which seemed to be deserving of more confidence.

The distribution in right ascension is as follows:

Group	I	5^h	28^m	to	7^h	9^m
Group	II	12	48	to	14	52
Group	III	17	19	to	19	26
Group	IV	21	29	to	23	28

Observation began October 1, 1896.

Groups	IV and I	were	observed	from	Oct.	1	to	Nov.	27,	1896
Group	I alone	was	"	"	Dec.	14	to	Jan.	11,	1897
Groups	I and II	were	"	"	Jan.	23	to	Mar.	13,	1897
Group	II alone	was	"	"	Mar.	16	to	Apr.	20,	1897
Groups	II and III	were	"	"	May	7	to	June	2,	1897
Group	III alone	was	"	"	June	18	to	July	4,	1897
Groups	III and IV	were	"	"	July	5	to	Aug.	26,	1897
Group	IV alone	was	"	"	Sept.	18	to	Sept.	28,	1897
Groups	IV and I	were	"	"	Oct.	4	to	date		

The internal probable error of a single determination as derived from each group separately is as follows:

I, 0″.135 II, 0″.139 III, 0″.137 IV, 0″.142

The reduction has been kept well in hand and results are available up to August 26th. They are as follows:

$\phi = 39° 58' +$

1896—Oct.	1-Oct. 31	IV 1″.878	I 1″.945	Mean 1″.912
Nov.	1-Nov. 27	1 .783	1 .939	1 .861
Dec.	14-Jan. 11		2 .079	2 .079
1897—Jan.	23-Feb. 16	I 2 .067	II 2 .117	2 .092
Feb.	23-Mar. 13	2 .060	2 .231	2 .145
Mar.	16-Apr. 20		2 .262	2 .262
May	7-May 21	II 2 .200	III 2 .322	2 .261
May	22-June 2	2 .202	2 .301	2 .251
June	18-July 4		2 .246	2 .246
July	5-July 31	III 2 .132	IV 2 .307	2 .220
Aug.	2-Aug. 26	2 .243	2 .291	2 .267

Although these results are in a manner preliminary it is not likely that any great modification will follow a more elaborate discussion. The agreement with Chandler's theory is very satisfactory, except that the last two values differ somewhat more than the computed probable error would lead us to anticipate.

For the purpose of illustrating more fully the character of the work, the individual values are given for group I, Dec. 14 to Jan. 11. The third place given above is the mean of these.

	1	2	3	4	5	6	7	8	9	10	Mean
1896 Dec. 14	2″.34	2″.25	2″.21	2″.44	2″.39	2″.30	2″.35	1″.90	2″.32	2″.28	2″.28
" " 23	2 .05	2 .32	2 .24	2 .59	2 .23	2 .13	2 .26	2 .18	2 .47	2 .08	2 .25
" " 24	1 .90	2 .01	1 .85	2 .33	2 .32	1 .96	2 .44	1 .83	2 .18	2 .47	2 .13
" " 25	1 .99	1 .73	1 .77	1 .90	1 .82	1 .67	2 .00	1 .72	1 .80	1 .91	1 .83
" " 27	2 .48	2 .19	2 .43	2 .25	2 .60	2 .56	2 .58	2 .41	1 .97	2 .03	2 .35
" " 28	1 .85	2 .16	2 .30	1 .88	2 .06	1 .85	2 .01	2 .10	1 .94	2 .01	2 .02
" " 31	2 .10	2 .34	.....	1 .85	2 .45	2 .20	2 .23	2 .34	.....	2 .15	2 .21
1897 Jan. 6	1 .87	2 .12	2 .14	2 .25	2 .09	1 .75	2 .07	2 .12	1 .72	2 .17	2 .03
" " 7	2 .12	2 .05	2 .48	2 .28	2 .13	2 .38	2 .18	2 .15	2 .25	2 .06	2 .21
" " 10	1 .95	1 .93	2 .30	1 .90	2 .60	2 .17	2 .54	2 .58	2 .56	2 .41	2 .29
" " 11	1 .91	2 .25	2 .29	2 .18	1 .92	2 .47	2 .29	2 .19	2 .15	1 .96	2 .16

These values are reduced to the mean declination of the group, hence they are strictly comparable. It will be observed that the extreme range is 0″.97. The probable error of a single observation computed from this series alone is 0″.127. That of a single night's work of ten determinations is 0″.40, yet it will be noticed that with one exception every value on December 25 is smaller than that determined from the corresponding pair on the 24th, and without exception smaller than the corresponding value on the 27th, the daily means being for the 24th 2″.13, 25th 1″.83, 27th 2″.35. Thus the difference between the 25th and 27th, $0''.52$, is thirteen times the probable error of an evening's determination.

Many series of zenith telescope latitudes have been examined, and in nearly every case similar anomalies have been found, in some cases the difference being much greater than the above. This seems to point unmistakably to some outside disturbing cause, presumably due to atmospheric disturbance. This will apparently be very difficult to deal with, but unless means can be found for doing so it would seem that we have about reached the limit of accuracy attainable in this class of work.

THE WORK OF THE COLUMBIA UNIVERSITY OBSERVATORY.

BY J. K. REES.

Professor Rees referred to the work of the Observatory staff on (1) The Determination of the Variation of Latitude at New York City; (2) The value of the Constant of Aberration by Küstner's Method; (3) The Reductions of the Measures of the Rutherfurd Photographs; and (4) Investigation of Polar Trail Plates.

(1) In April, 1893, arrangements were concluded between the Royal Observatory at Capodimonte, Naples, of which E. Fergola is the Director, and the Observatory of Columbia University for observing the same stars with two zenith telescopes, made by Wanschaff of Berlin. These instruments have apertures of eighty millimeters and focal lengths of one meter and are in all respects exactly alike. The two latitude levels on each instrument are by Reichel of Berlin. Before leaving Berlin the instruments were tested by Dr. Albrecht. Fifty-six stars, divided into four groups of seven pairs each were observed. The investigation of the declinations of these stars was made by Professor Jacoby and Dr. Davis, and has been published as Part 1, *Memoir I of the New York Academy of Sciences.* This publication is also No. 8 of the *Contributions from Columbia University Observatory.* Both Observatories have issued recently preliminary publications of the results of their work for the period May, 1893 to July, 1894.*

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*"The Variation of Latitude at New York and a Determination of the Constant of Aberration from Observations at the Observatory of Columbia University," by J. K. Rees, H. Jacoby, and H. S. Davis, *Astronomical Journal,* No. 401.

"Novella Determinazione della Constante dell' Aberrazione e della Latitudine di Napoli da Osservazioni fatte nel R. Osservatorio di Capodimonte negli Anni 1893-94 per E. Fergola.

The following table shows the variation of latitude at the two places:

AT NEW YORK CITY

Date		Latitude*	Variation
1893—May	19,	40° 48′ 22″.19	+0″.00
June	18,	.20	+ .01
July	14,	.21	+ .02
Aug.	1,	.09	— .10
Oct.	17,	.28	+ .09
Nov.	15,	.16	— .03
Dec.	13,	.27	+ .08
1894—Jan.	18,	.18	— .01
Feb.	15,	.19	— .00
Mar.	14,	.17	— .02
April	12,	.21	+ .02
May	15,	.19	— .00
June	13,	.13	— .06

Mean 22″.19

*The Latitude Observatory is about three and one-half miles north of the University Observatory.

AT NAPLES

Date		Latitude	Variation
1893—May	18,	40° 51′ 45″.72	—0″.02
June	16,	.70	— .04
July	16,	.70	— .04
Aug.	14,	.67	— .07
Sept.	12,	.68	— .06
Oct.	16,	.73	— .01
Nov.	12,	.76	+ .02
Dec.	14,	.78	+ .04
1894—Jan.	17,	.74	+ .00
Feb.	14,	.81	+ .07
Mar.	14,	.75	+ .01
April	15,	.81	+ .07
May	14,	.82	+ .08
June	13,	.78	+ .04

Mean 45″.74

At Naples Professor Fergola observed alone. His latitude determinations depend upon 2271 pairs of stars. At New York City, the observers were Professors Rees and Jacoby and Dr. Davis. These observed 1774 pairs of stars, as follows: Rees 809; Jacoby 299; and Davis 666.

Since July, 1894, the observations have been continued, but on a reduced scale. Four good nights every two weeks are sought. The observations at Naples are now being made by Doctors Angelitti and Contarino, and the observations at Columbia University, by Professor Rees and Dr. Davis. Results of the latter series will be ready soon for publication. In this connection it is proper to state that the complete reductions of all the observations as Part 2, *Memoir I of the New York Academy of Sciences,* and No. 9 of the *Contributions from the Columbia University Observatory* will be made with funds provided by the generous contribution of Miss Catherine W. Bruce, of New York City.

(2) At New York City and at Naples, the Constant of Aberration has been determined from the first series of observations without making any assumption in regard to the law of latitude variation, either as to period or as to amplitude. The value obtained at the Columbia Observatory was 20″.46, and at the Royal Observatory at Naples, 20″.53. The difference in the results seems to indicate that there is some systematic error in the method, unless some error be discovered in the computations which will bring them into better agreement. Circumstances were unusually favorable to the method, and a better agreement was to be expected. In the present state of our knowledge, we prefer to leave further conclusions to await the reductions of the later series of observations.

(3) The son of Lewis M. Rutherfurd, Rutherfurd Stuyvesant, Esq., has provided the means since his father's death for carrying on the work of the reductions of the measures of the star plates made by Rutherfurd, and also for measuring the plates unmeasured by Rutherfurd, and for reducing such measures. Mr. Stuyvesant has also provided the means for making the various publications. The work has been under the special charge of Professor Jacoby.

The Observatory has published in the *Annals of the New York Academy of Sciences,* and in its own *Contributions,* the following papers:

By Professor Jacoby:

The Rutherfurd Photographic Measures of the Group of the Pleiades.

The Rutherfurd Photographic Measures of the Stars about β Cygni.

The Parallaxes of μ and θ Cassiopeiae, from Rutherfurd Photographic Measures.

On the Reduction of Stellar Photographs, with special reference to the Astro-Photographic Catalogue Plates.

On the Permanence of the Rutherfurd Photographic Plates.

By Dr. H. S. Davis:

The Parallax of η Cassiopeiae deduced from the Rutherfurd Photographic Measures.

The Rutherfurd Photographic Measures of sixty-two Stars about η Cassiopeiae.

The Parallax of 61 Cygni, from the Rutherfurd Photographic Measures.

The Parallax of Bradley 3077, from the Rutherfurd Photographic Measures.

All of the Rutherfurd Photographs were made with wet plates. He left a number of important plates unmeasured. Before proceeding to the measurement of these plates on the Repsold machines belonging to the Observatory, the investigation on the permanence of the Rutherford plates was made. This investigation showed that measures can now be undertaken without any apprehension as to the movements of the collodion film.

Mr. Frank Schlesinger, Fellow in Astronomy, and Mr. W .C. Kretz, University Scholar in Astronomy, are now at work measuring and reducing the plates of the Præsepe Cluster, and the Cluster in Coma Berenices.

(4) Professor Jacoby has undertaken the measurement of polar trail plates made at his request by Dr. Donner, of Helsingfors. From the reduction of these measurements, he hopes to get a fundamental system of right ascensions and polar distances of the close polar stars. The method may, in the future, lead to values of the constants of precession, nutation, and aberration, which will be superior to the best meridian determinations. The results of the preliminary investigations will shortly be made public.

THE PHOTOCHRONOGRAPH.

BY JOHN T. HEDRICK, S.J.

The instrument used at the Georgetown College Observatory for the photographic registration of star transits was devised by the Rev. George A. Fargis, S.J., and was the sequel of one devised by Professor Frank H. Bigelow of the Weather Bureau, whose first experiments had been made at Harvard with the help and suggestions of Professor Pickering. In Professor Bigelow's instrument, the photographic plate, enclosed in a holder, was moved up and down each second by an electro-magnet in a clock circuit. The motion broke up the continuous trail, which would have been made by the star as it crossed the field, into two parallel lines of dots or dashes, each impressed on the plate during a given second of time. The reticle, which lay a little in front of the plate, was then impressed on it by throwing a light through the object glass and down the telescope, thus slightly fogging the plate, except where it was covered by the wires of the reticle, which showed bright on a darkened ground. (Professor Bigelow's device was shown).

Professor Bigelow being called away from Washington for some time, further experiments were undertaken by Father Fargis to remove what seemed to be imperfections in the first device. These were, the motion of the plate, the weight of the moving parts, the danger of parallax on account of distance between the reticle and the plate, which was needed in order to permit the motion of the latter, and the fogging of the plate in the neighborhood of the rows of star images when photographing the reticle on the plate.

The method of doing this last was retained, as it did not seem to leave anything to be desired, if the neighborhood of the star images could be protected. Instead of spider lines a glass plate was used on which a single line was ruled. This was interrupted for a short distance in the middle of the field, so as not to interfere with the star images. The plate holder was discarded and the bare plate used. As the plate had not to move, it was placed and held firmly almost in contact with the glass reticle. With a somewhat different arrangement it might have been quite in contact. In order to break up the star trail into portions impressed on the plate at definite times, the following arrangement was devised. A small electro-magnet had fastened to its armature at right angles a thin strip of steel, long enough to reach nearly across the field of the telescope and broad enough to cut off the cone of light from a star at a point near the focus. The whole weighed only a few ounces, the moving parts weighing only about a quarter of an ounce or less. It was carried by a clamp-ring around the draw tube of the telescope and was placed near the reticle end, the steel finger, or shutter, stretching across the field through an opening in the drawtube a little on the object-glass side of the reticle. The electro-magnet was in the clock circuit. (This instrument, the photochronograph, was shown).

The action of the photochronograph may be explained by a comparison with the ordinary register of clock times on a barrel chronograph. The telescope was so set that, with the armature of the electro-magnet down, the image of the star fell on the steel finger, or shutter, and was cut off from the plate. The breaking of the circuit by the clock, instead of making a signal on a sheet of paper, released the armature, causing the shutter to rise and allowing the star image to fall on the plate while the break lasted. Thus a series of impressions on the plate took the place of the ordinary register. The clock times were written on the plate instead of on the chronograph sheet and by means of the light of the star. This suggested the name given the instrument. When a sufficient number of impressions had been secured, a light was thrown through the objective and the reticle photographed directly on the time scale, thus doing automatically what the observer does by his signals in the ordinary chronographic registry of transits. While the reticle was being photographed, the shutter was kept covering the row of star impressions, protecting this part of the field from fogging. (Some plates containing transits were shown).

When the plate is measured in the microscope-micrometer, the time of transit over the wire can be deduced from each impression. By pairing those nearly symmetrical with the wire, in a full transit the micrometer screw-value is never needed to determine more than half an equatorial second. The screw-value itself is found from the time scale, or row of star images. This measurement of the plate gives rise, of course, to the possibility of personal equation. Such was actually found in the Georgetown plates, arising seemingly from the use of a single wire in the micrometer. But in the photographic method, the transit is fixed on the plate, which may be measured by many persons, at any time and in any way which may be devised for eliminating personal error.

In order to test the method, the Ertel transit of the Georgetown College Observatory was fitted up and an extensive trial made. The results of this trial have been published. The following are the conclusions which are of particular interest.

As determined by the agreement *inter se* of the impressions on single plates, the probable error of a single image was ± $0^s.035$. Albrecht's *Hülfstafeln* give for the magnifying power of our telescope and microscope combined, at the equator, ± $0^s.075$ for eye and ear and ± $0^s.057$ for the chronograph, and the same as for the photographic method at the declination 71°.4 and 66°.0, respectively. The breadth in declination of the star images was usually from 3″ to 5″. Contrary to expectation, it was less with increasing declination.

The usual time of exposure was a tenth of a second. With this stars could be taken down to $3^m.5$, or sometimes fainter ones, though not all of $3^m.5$ could be taken. Some stars had a whole second exposure, but enough were not taken to form a judgment. The aperture of the Ertel transit is 4½ inches and its focal length 78 inches, or the ratio is 1 to 17. For several reasons, the photochronograph has been used in a series of observations for latitude by photography.

With a whole second's exposure, stars could ordinarily be taken as faint as the sixth visual magnitude. The zenith telescope used is better adapted to photography. Its aperture is six inches and its focal length thirty-six inches, or the ratio is 1 to 6. Such a telescope does not differ widely in weight and cost from the usual portable transit.

Obviously, one of the principal applications of the photochronograph is to the determination of longitudes. The probable error of the clock correction when at its minimum was found to be $\pm 0^s.01$. Its square at the time T, in hours from the moment of minimum probable error, was found to be $(0^s.01)^2 + (0^s.01)^2 T^2$. The average number of stars each night which gave these probable errors was twenty, including both time and azimuth stars. As there were no collimators, the method usual with portable instruments was followed, the instrument being reversed in its V's during each night's work.

PERSONAL EQUATION IN LONGITUDE DETERMINATION.

BY HENRY S. PRITCHETT.

All determinations of the difference of longitude of two meridians consist of two operations, whether the method employed be that of telegraphic determination, moon culminations, or occultations. These operations are:

(1) The determination of the local time at each station.

(2) The comparison of timepieces.

By the telegraphic method, clocks a thousand miles apart can be compared, over land lines, with practically the same accuracy as if they stood in the same room. The errors, therefore, of the longitude determination are to be found in the first of the operations mentioned; namely, in the determination of the local time.

In the star observations made at each station, every star observed will give an equation of the form:

$$\alpha - t = \Delta t + Aa + Bb + Cc + k,$$

where α denotes the right ascension; t, the observed time; Δt, the clock correction; a, b, c, the azimuth, level and collimation constants respectively; and k, the correction for diurnal aberration.

It is desired to determine Δt, the clock correction; with ten or twelve stars properly chosen, the effect of azimuth and collimation is completely eliminated; the correction for aberration is a small one, and is known with great exactness. The uncertainties in right ascension will not affect the agreement of results from night to night if the same list of stars is employed. There remain, therefore, only two terms in this equation whose uncertainty will cause discrepancies in the individual results. These are (1) errors in the level constant *b*; (2) errors in the observed time *t*.

I. The effect of errors in the level is probably more serious than is generally suspected. A slight pinching of the tube in the cell and the consequent change of the radius of curvature may make sudden and rather large changes. These, however, are not now under consideration.

II. The errors in *t* are due to accidental errors and to personal equation in observing star transits.

It is generally considered safest to change observers and consider the personal equation eliminated thereby. For some years past the writer has made a large number of determinations of longitude in conjunction with Mr. S. S. Gannett, of the U. S. Geological Survey. The personal equation could not be got rid of by exchanging observers. It has, therefore, been determined at the beginning and end of the season's work. The determination was made by setting up two transits on two piers in the Observatory of Washington University, St. Louis, and determining their difference of longitude in exactly the same way that the regular longitude determinations were made, taking all possible precautions to avoid the effect of contiguity.

The following results show the probable errors of a single night's work (from the individual longitude results) for different distances. The first result is the probable error in the determination of the longitude of the two piers, which were only six feet apart.

Probable error of one night's exchange	Distance between Stations in miles	Number of Repeaters in circuit
± $0^s.048$	0	0
± 0 .041	271	0
± 0 .049	585	1
± 0 .031	1531	2

As these results depend upon a large number of observations, extending over six years, they may be considered as fairly indicating the relative probable errors under the different circumstances mentioned.

Two conclusions seem fairly safely shown:

In the first place, the accuracy of longitude determinations over land lines seems independent of the distances.

Secondly, the experience of the two observers seems to indicate that their relative personal equation, while fairly constant from year to year, was subject to sudden and large fluctuations from night to night, and even in the progress of a night's work.

A POSSIBLE FORM OF MIRROR FOR REFLECTING TELESCOPES.

BY CHARLES LANE POOR.

The mirror in question is a section of a paraboloid of revolution, cut at the extremity of the latus rectum. Such a mirror has the property of bringing to a single focus all the rays parallel to the axis of figure, and the axis of the reflected pencil is perpendicular to that of the incident beam; the mirror thus performing the functions of a parabolic mirror of the ordinary form and of a plane mirror placed at an angle forty-five degrees.

The advantages of this form are, *first,* that a single reflection takes the place of two; *second,* that there is no secondary mirror in the path of the incident rays. Thus the entire surface of the mirror is utilized and the image should be free from the diffraction bands caused by the support of the flat in the old style; *third,* the resulting form of equatorial mounting is extremely simple. The telescope tube becomes the declination axis, the mirror being mounted at the extremity of this axis in a manner entirely similar to that of the large flat of the equatorial coudé. The image formed by the mirror is therefore at the intersection of the declination and the polar axis. and remains in a constant position, no matter on what part of the heavens the telescope may be directed. This offers great advantages for the observer, and for the attachment of special appliances, such as spectroscopes. Further, no dome is required.

From experiments made at the Johns Hopkins University in grinding and polishing such a mirror, it may be safely concluded, that such a form, while extremely difficult to make, is not impossible. A small mirror has actually been constructed on these lines and is now being experimented with.

It was suggested that further experiments be carried out at the Yerkes Observatory, the facilities for glass working in the latter place being far superior to those of the Johns Hopkins University.

THE SOLAR MOTION AS A GUAGE OF STELLAR DISTANCE.

BY SIMON NEWCOMB.

1. The numerical quantity of the solar motion, expressed in units of terrestrial measure, say kilometers per second, can best be determined by measurements of the motion of stars in the line of sight. I find that Vogel's measures give a velocity of about ten kilometers

per second, with a mean error of perhaps one-half its amount. While these measures are not sufficiently numerous to lead to a definite result, it may be hoped that, in the not distant future, more determinations will be made.

2. The parallactic motion of a single star does not admit of absolute determination. But for groups or classes of stars situated not near the sun-way apex or anti-apex, the motion can be determined. In my investigation of the precessional constant I found evidence that the mass of the Bradley stars of magnitude 6 and upwards near the sun-way equator have a parallatic motion exceeding 2″ per century, this quantity being near the limit of the motion for the stars in question.

3. From these two data it would follow, by a very simple computation, that the great mass of the Bradley stars are contained within a sphere whose surface has an annual parallax of 0″.01.

4. In the same paper (p. 24), I found that the Bradley stars whose parallatic motion exceeds 10″ per century probably numbered about 342. From a solar velocity of 10 kilometers per second it would follow that these stars have an annual parallax of 0″.05 and upwards.

5. The determination of the parallactic motion of the fainter stars is among the desiderata of astronomy in the immediate future. Very valuable for this purpose would be the re-observation of the Harvard equatorial zones, found in the earlier volumes of the *Harvard Annals.* These have the great advantages that each star was observed twice, and that much fainter stars are included than are found in the older zones.

ON THE MEANING OF THE STAR MAGNITUDES OF FATHER HAGEN'S ATLAS OF VARIABLE STARS.

BY J. G. HAGEN, S. J.

As to the general plan of the Atlas Father Hagen referred to his account given a year ago at the astronomical meeting in Bamberg, and printed in the *V. J. S.* Bd. 31, s. 278. The accuracy intended in the *positions* of the stars in the Atlas will be sufficiently understood from the preface of the work, but the *magnitudes* of the stars seemed to call for an explanation.

The brightness of the stars was not estimated directly in magnitudes, but in relative steps between the stars, and the question arose how to transform these steps by computation into magnitudes.

Before answering this question it may be instructive to compare the work of this Atlas with that of a *Durchmusterung.* The purpose of the latter is to spread a uniform scale of magnitudes all over the sky, while accidental errors in the individual star magnitudes are of minor importance. In an atlas, however, which is to serve for the light variations of the stars, the relative brightness of the comparison stars is the main purpose, while a uniformity of scale between the individual charts is of little consequence. Now it is admitted by all observers of variable stars that the relative brightness of the stars is obtained with greater accuracy from steps than from magnitudes.

In transforming the steps into magnitudes the first condition must be to adapt the computed scale of magnitudes as closely as possible to some standard scale already existing. It was shown in the lecture at Williams Bay, that this condition is incompatible with a uniform lower limit of magnitude for all the charts, and that this limit varies within the magnitudes 11½ and 13½, for the Georgetown refractor of twelve inches aperture. It will be sufficient here to mention that this variation of the limit of magnitudes was referred to several causes. First, the limit of visibility in any instrument cannot be assumed to be the same for all parts of the sky and all times of the year. Then the light ratio from the brighter to the fainter stars cannot be assumed constant in any scale which was made without photometric instruments. Finally the scale itself may not be uniform for all parts of the sky.

Considering these uncertainties it was thought best to compute for each chart a step value which would bring the computed magnitudes in close agreement with a standard scale, say the Bonn *Durchmustering,* and to apply the same to the fainter stars, without regard to the limit reached on the several charts. In using the charts and the accompanying catalogue it must then be borne in mind that the magnitudes assigned to the stars below the tenth magnitude are by no means meant to be a *continuation of the BD. scale,* but merely *the result of a computation, in which a close agreement with the BD. within the magnitudes 7 and 10 was intended, and where the step-value thus found was applied to the fainter stars, without regard to the limit which would be thus reached.*

These magnitudes fully answer the purpose for which they are intended, viz., to enable the engraver to represent on the charts the relative brightness of the stars. The observer of variable stars will thus be enabled to recognize the configuration and to identify the variable, while in his reductions and computations of the light curve and period of light variation, he will discard the magnitudes altogether. He will not even use the steps, printed in the second column of the *Catalogue*, except as a guide in choosing his comparison stars, because his observations will furnish him his own scale. The steps may be of use later when a photometric scale shall have been constructed for the fainter stars. It will then be an easy matter to determine, by a graphical process, the varying step-values by which our steps are adapted to this or any other new scale. A specimen chart was passed around during the lecture, and the columns of the *Catalogue* were represented on the blackboard. At the end of the lecture the announcement was made that Miss Catherine W. Bruce had liberally granted the indemnity for the publisher, which was necessitated by the great expense of the engraving. It was mentioned also that astronomers owe this gift to the kind commendation of Professor E. C. Pickering. These announcements were received with applause. It may be added that the I Series of the Atlas is now in print, and the publication is in charge of Mr. F. L. Dames, Berlin.

THE SYSTEM OF BETA LYRAE.

BY G. W. MYERS.

This paper has since been printed in full in the *Astrophysical Journal* for January, 1898, Vol. 7, pp. 1-22.

JOVIAN PHENOMENA.

BY G. W. HOUGH.

The planet Jupiter exhibits the greatest variety of phenomena of any planet belonging to the solar system. The surface markings may be seen with a small telescope, and from the time of Galileo to the present day the planet has been studied by astronomers, and a great number of facts have been collected regarding the changes taking place on the surface. Until within recent years it seems to have been assumed that there was no great degree of permanency in the markings.

New belts are stated to have been formed in a few hours, and in the course of a month or two the whole aspect of the disk was changed.*

I began a systematic study of the physical features of the planet in 1879 with the 18½-inch refractor of the Dearborn Observatory, and have continued the observations to the present time.

Very early in my study it seemed to me that the surface exhibited

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*See Grant's *History of Physical Astronomy*, etc.

a much greater degree of permanency than had hitherto been admitted. The result of eighteen years of observations shows that the changes which are continually taking place on the surface of the planet are effected in an orderly manner; some of the prominent features persisting for years with very slight changes in form or position on the disk. The south margin of the equatorial belt and the great red spot are conspicuous examples of permanency. In order to deduce conclusions of any value, regarding the condition of the surface of any planet, it is desirable to have a continuous record of phenomena over a long period and not isolated observations at irregular intervals. The astronomer of today, provided with the largest telescope, and most favorable atmospheric conditions, can not formulate a theory regarding the physical condition of a planet, which will be of any value to science, by simply noting what is seen with his telescope during one night or one opposition. During recent years statements have occasionally been made with regard to the variation in magnitude and displacement of objects on the disk of Jupiter, which, unless properly interpreted, are misleading as to the nature of the actual phenomena. The following considerations will elucidate the subject:

1. As the observer is looking at a rotating globe, having the axis nearly perpendicular to the line of sight, objects will cross the disk in nearly straight lines, but the linear velocity will be greatest at the equator and least in higher latitudes.

2. All objects, when they are brought in view by rotation, will be infinitely short, and as they advance farther on the disk, the apparent length will increase until the center of the object is on the middle of the disk, when it will be the longest possible; after it passes the center, the length will appear gradually to shorten until it passes behind the disk at the preceding limb.

3. In case a spot near the equator and one end of the great red spot happen to lie on a line parallel to the polar axis of the planet, the equatorial spot may deviate from this line two or three seconds of arc, while under the eye of the observer; owing to the change in the length of the red spot as well as the unequal linear velocity due to difference of latitude.

From 1879 to 1884, two conspicuous equatorial white spots passed the great red spot at intervals of forty-five days, when the apparent shifting of the spots with reference to each other was well illustrated.

4. During the revolution of the planet in its orbit, all objects on the disk will be displaced in latitude, due to the elevation of the earth above Jupiter's equator. Objects near the equator of the planet

may be displaced $\pm 1''.1$ of arc, and those in higher latitudes a less amount.

5. On account of the rapid foreshortening of the degrees of latitude in the polar regions, spots or detached markings are found only in the equatorial and middle latitudes. It is seldom that a spot is seen beyond the parallel of 40°.

The parallel of 70° is at one second of arc and that of 80° at one-fourth second of arc from the limb, hence the polar regions are entirely beyond our reach.

6. Since all markings are only seen in their normal proportions when on the central meridian of the disk, it would be a difficult matter to decide whether any actual change occurred in the shape or size of the object in its passage across the disk.

In 1880 when the red spot was most intense in color it was seen coming on the disk when the true center was at 88° from the central meridian and its computed length one second of arc. When the spot is wholly on the disk, the true center is 71° from the central meridian and the apparent length is $3''.71$. When the center is on the central meridian the length is $11''.61$ or $37^\circ.6$ of longitude and the breadth is $3''.6$.

In the study of the surface markings on Jupiter, the longitude, latitude and magnitude of the object has invariably been determined with the micrometer. For all micrometer measurements, however, which are referred to a luminous disk, it is essential to employ both limbs, in order to eliminate the effect of irradiation, or what is of greater importance the enlargement of the disk due to bad definition.

The great red spot has been observed during every opposition since 1879 and its motion in longitude and latitude ascertained.

The equatorial belt and the various black and white spots have also been observed annually, except during the year 1888 when the telescope was dismounted.

The true rotation period of the planet is unknown, and hence we are unable to use a fixed zero point for longitude. Since 1879, however, the great red spot has been used as the reference point, and ephemerides have been published annually by Marth, which have been of great value for the proper reduction of observations. The great red spot has had a gradual, but not uniform retrograde drift in longitude during the whole interval.

The rotation period of the planet, as given by the red spot, was as follows:

1879	$R = 9^h$	55^m	$34^s.2$
1886			39 .9
1896			41 .4

The spot has also drifted in latitude, the total displacement being 2″.1. The maximum latitude (distance from the equator) was —7″.41 in 1886, minimum value — 5″.32 in 1892.

The shape and size of the spot has, however, remained nearly constant during the whole period of its visibility. It appears to be one of the most permanent features on the disk. The equatorial belt has shifted in latitude both at the north and south margins. The belt has also changed in width, due to dissipation of the material of which it is composed, or submergence below the surface. The changes are possibly periodic during the Jovian year, due to meteorological causes. The gradual change in the size of the marking, the slow drift in longitude and latitude, show that the surface is in a plastic condition, but its exact nature is as yet unknown. The great permanency exhibited in some of the markings proves conclusively that the phenomenon is not atmospheric, as we use the term, but the medium in which the great red spot and equatorial belt are floating may have a density approximating that of a liquid.

ASTRONOMICAL PHOTOGRAPHY WITH SMALL LENSES.

BY E. E. BARNARD.

The photographs exhibited were made with the Willard six-inch portrait lens during my connection with the Lick Observatory. This lens was about thirty-one inches focus and was originally in the possession of a photographer in San Francisco, where it had been used in the early days of wet plate work, and was purchased by the Lick Observatory for a small sum. It was refigured by Brashear and in the first work (before refiguring) was strapped to the six-inch equatorial as a guiding telescope. It was later attached to an ordinary equatorial mounting which did not permit the exposure to be carried over the meridian. A small two-inch telescope was used to guide by when so mounted. The lens was made by Willard, New York, in 1859.

I had previously attempted to photograph the Milky Way at Nashville and at the Lick, but the lenses were not suited for that purpose. I believed that it could be done if the proper lens could be had. This large portrait lens proved to be the instrument best suited for the work, and the first photographs ever made to show the structure of the Milky Way were secured with it in July and August of 1889.

This lens was used not only for photographing the Milky Way and the nebulae, but also for the photography of comets and experimental work on the earth-lit portion of the new moon.

Description of the pictures.—Several different views of the crescent moon were thrown upon the screen, showing the earth-lit portion of the lunar world. The details on the dark part were clearly shown with less than half a minute's exposure. These pictures showed that the solar rays after having been reflected from the earth's surface to the moon and thence back again to the earth, were sufficiently strong in actinic power to give a clear and distinct picture of the moon's surface during the lunar night.

It was suggested that a photometric study of such photographs might lead to very interesting results concerning the changing reflective power of the earth due to the distribution of land and water and clouds as seen from the moon at different times. It was further found that with a small "lantern lens" 1½ inches in diameter, and 5 1-3 inches focus, the dark part, when the moon was a thin crescent, could be readily photographed in one second—thus showing the enormous increase of effective light-grasping power of the smaller lens over the larger one.

A photograph of the total lunar eclipse of 1895, September 3, when the moon was near the center of the earth's shadow, showed the moon and its surface detail clearly and sharply defined. The exposure was seven minutes, which was much longer than necessary to show the details when in the shadow. A number of photographs, up to twenty-three minutes exposure, were made during the eclipse with the main purpose of a search for any possible satellite to the moon, which might at the time be outside the shadow and thus be caught by the sensitive plate, while the light of the moon itself was dimmed. Nothing was shown that would indicate the existence of a satellite to the moon as bright as the eleventh or twelfth magnitude.

A photograph of the solar corona at the total eclipse of January 1, 1889, made with a 3½-inch non-photographic telescope reduced to 1¾ inches, showed not only the details close to the moon's limb, but also the great equatorial extensions of the corona and the beautiful symmetrical polar fans. The exposure was only 3½ seconds. Attention was called to the fact that great care was required in the development of such a picture, to avoid the burning out of the bright details of the inner corona.

Various photographs of different portions of the Milky Way showed the remarkable structure of the galaxy. Particular attention was called to the vacant lanes and black holes and geometrical arrangements of the stars at certain points. Many portions of the Milky Way seemed to consist of thin sheetings of stars with enormous black rifts in them as if these portions were breaking up. The most remarkable of these pictures was one showing the extraordinary appearance of the sky about the great nebula of Rho Ophiuchi. The nebula (which was discovered with the Willard lens) was shown to occupy a great vacancy among the stars, from which sharply defined vacant lanes ran eastward for many degrees. This entire region seemed to be nebulous, and the smaller stars—which seemed to be of a uniform size—appeared to be actually mixed up in this nebulosity. From the fact that the nebulosity was connected also with some of the bright naked-eye stars of this region, there was good reason to believe that the smaller stars here, forming the groundwork of the Milky Way, must be really very small bodies compared with our sun, for, from their connection with the nebula, they appear to be at the same distance as the bright stars which were also connected with the same nebula, but which were themselves comparable in size with our own sun.

Some of the photographs showed vast regions of the Milky Way to be involved in diffused nebulous matter; such as the regions of 15 Monocerotis, in Cepheus, in Cygnus, etc. These pictures gave the impression that the stars at those points were freely mixed up in this nebulosity without any special tendency to individual condensation which is a striking feature of the diffused nebulae of the sky.

Many photographs of nebulae were exhibited—especially the exterior nebulosities of the Pleiades where streams and masses of nebulosity, connected directly with the Pleiades, were shown to exist for many degrees about the cluster.

A picture of the great curved nebula, extending over almost the entire constellation of Orion, showed what wonderful power lay in the small lantern lens for work of this class. The best exposure for this object, with this lens seemed to be about one hour. The brighter portion of the nebula, near 56 and 60 Orionis had, however, been distinctly shown on a photograph with the Willard lens, with three hours exposure.

An enlarged photograph of the great nebula in Andromeda, showed clearly the ringlike structure of the nebula, and all the features that had been previously photographed.

Photographs of the comets of Swift, Holmes, Brooks, and Gale, showed the remarkable features of these bodies, and the extraordinary changes that utterly transformed them night after night. Brooks' comet of 1893 was perhaps the most remarkable of these bodies. Successive photographs of it showed the tail shattered and broken in a most extraordinary manner. To explain the appearances of the tail, it was suggested that some force outside that existing in the sun and comet must have produced these malformations. Such distortions would probably be produced by the encounter of the tail with some resisting medium—such as meteor-streams or swarms, which we know exist in space. One of the pictures, which showed the tail bent abruptly at right angles, near its end, could only be explained by supposing some external force of this kind.

Among the pictures was one of the discovery of Comet V 1892. A fuzzy trail was found on developing a star plate on October 12, 1892. This was suspected to be due to a comet, which was actually found upon searching for it in the sky. This comet was subsequently observed at the principal observations in the world, and was found to be moving in an ellipse with a period of about six years. The picture is unique, as it contains the only actual discovery of a comet by photography.

A photograph of Brooks' comet on the morning of November 14, 1893, showed a fine meteor trail crossing the plate near the comet. The beginning of the trail—where the meteor first struck the atmosphere—is shown, but it passed off the plate before exploding. Three other meteor photographs were exhibited—one of a stationary meteor. The other two pictures were of the same meteor with two different cameras, and were obtained at the Yerkes Observatory, August 10, 1897.

The paper was concluded by the exhibition of a number of photographs of the Milky Way made with the small "lantern lens." These showed what extraordinary results could be obtained with such modest means—where the lens cost only a few dollars.

It was found that this small instrument would readily photograph in ten or fifteen minutes what it took the Willard lens from three to four hours to show. It had proved specially fine for photographing such diffused nebulosities as that connected with the great nebula of Rho Ophiuchi, which was shown by it to extend some degrees west of Antares. With this small lens the great wing-like nebula about Nu Scorpii was discovered. A sufficient number of photographs had been made with it partially to construct a map of the Milky Way, which, while showing vastly more than the eye could see, would more nearly resemble the naked eye view of the Galaxy.

RESEARCHES ON PLANET (334), CHICAGO.

BY KURT LAVES.

Planet (334) was discovered by Professor Wolf at Heidelberg, by the photographic method on August 23, 1892, and at the Astronomical Conferences at Chicago, August 1893, he gave it the name "Chicago," in memory of the World's Fair event. From photographic observations of August 23 and 29, 1892, Mr. Berberich derived a circular orbit with a mean daily motion of 460″. At the time of the discovery the magnitude of the planet was the twelfth. Dr. Palisa of Vienna succeeded in finding the planet with the equatorial of twenty-seven inches on November 22, and up to December 8 of the same year secured altogether four observations. Two more observations were obtained from Professor Wolf's photographic plates in the months of October and November. Uniting all of these observations Mr. Berberich has derived a first set of elliptical elements which he has published in *Astronomische Nachrichten,* No. 3202. In this note Mr. Berberich calls attention to the large perturbations which this planet undergoes from Jupiter. He obtains for 1893, November 16, the following perturbations of the elements:

$$
\begin{array}{lcrrrl}
\delta M & = & +30^\circ & 38' & 50''.8 \\
\delta \omega & = & -30 & 38 & 9\ .9 \\
\delta \Omega & = & -\ 0 & 18 & 59\ .7 \\
\delta i & = & -\ 0 & 0 & 41\ .4 \\
\delta \phi & = & -\ 0 & 18 & 2\ .3 \\
\delta \mu & = & - & & 4\ .115
\end{array}
$$

Indeed the distance, (334)—Jupiter, becomes quite small, so small that in 1894 it decreased to 1.25 units, the radius vector of (334), being 3.90 units. The perturbing force of Jupiter compared with the attracting force $=(1/1047)\,.\,(3.90/1.25)^2=1/108$.

In the case of Saturn the same fraction is but 1/250. During the next opposition the only observations obtained are those by Dr. Palisa on December 3, 4, 31, and January 2, 1894. Mr. Berberich has united all of the observations between 1892 and 1894 and arrives at the following set of elements.

Epoch, November 16, 1893, Berlin M. T.

$$
\begin{array}{rcl}
M & = & 278^\circ\ \ 45'\ \ 55''.1 \\
\left.\begin{array}{rcl}
\omega & = & 347\ \ \ 34\ \ \ 11\ .3 \\
\Omega & = & 135\ \ \ 50\ \ \ \ 3\ .3 \\
i & = & 4\ \ \ 33\ \ \ 26\ .9 \\
\phi & = & 0\ \ \ 25\ \ \ 14\ .5
\end{array}\right\} & & 1900.0 \\
\log a & = & 0.593775 \\
\mu & = & 456''.3980
\end{array}
$$

In 1897 the planet has been observed at the Algiers Observatory and seven observations were secured. (*Bulletin Astronomique,* Sept. 1897). Professor James Hart, of Maine State College, has examined the perturbations of Jupiter on the planet between November 16, 1893 and May 10, 1895, by the method of special perturbations. He has found a perturbation in μ, $\Delta\mu = -2''.841$, $\Delta\phi = -13' 24''.6$. The planet, therefore, very closely approaches the case where $\mu = 450''$ is fulfilled. On this account long period inequalities will become very sensible, and the planet deserves special attention first, since it comes so near to Jupiter, and second, since the mean motions of the two are so nearly commensurable. The perturbing action of Jupiter will decrease the eccentricity until it becomes zero; an increase to negative values will mean a change of the perihelion by 180°. The value of $\Delta\omega = -69° 31'$, which Mr. Hart has found is not well enough determined and can be regarded only as an approximation. This is due to the method employed. The variation of the elements, especially those of ω and M, are so considerable that new elements should be derived after every period of forty days. This has not been done, but the same set has been retained during a year and a half. Mr. Hart's work had advanced too far before I noticed the desirability of such a change; we must therefore regard his results, so far of ω and M are concerned, as approximate only.

Mr. Moulton and I have recently attempted to derive general tables for planet (334). Leverrier's method of absolute perturbations has been used, since the small eccentricity and the small inclination of the planet seemed to recommend this method in the first place. The great advantage which the smallness of e and $\eta = \tan \frac{1}{2} I$ presents, is somewhat counterbalanced by the greatness of the value of $\alpha = a/a'$ which amounts in this case to 0.7543. The coefficients of the development depend upon the expansion of

$$(1 + a - 2a \cos w)^{-s} = \tfrac{1}{2}\Sigma L_s^{(i)} \cos i w,$$

where s assumes the values 1/2, 3/2, 5/2, 7/2. In the second volume of the *Annales de l'Observatoire de Paris,* Leverrier gives the general expressions for the $L_s^{(i)}$ quantities from $i = 0$ to $i = 15$. This limit is not exceeded in any of the larger planets, since only in the case of Venus and the earth does α amount to 0.723, and here the mass of the perturbing planet is less than 1/300 of the mass of the perturbing planet in the present case. When neglecting in the perturbations of the elements quantities $< 0''.1$ we have to go in the absolute terms to $i = 25$. The last quantity in the periodic terms will therefore be of the nature

$h \cos 25\,(l' - \lambda)$. Since the coefficients are small and decrease uniformly, the additional work is not very heavy, since an extrapolation will give sufficiently accurate results in the last values. We have completed the determination of the secular perturbations including the third power of small quantities. In the periodic terms the perturbations including the second powers are nearly finished. The extension of this work from $i = 15$ to 25 is not yet done. Nor have we yet ascertained to which power of small quantities the work will have to be pushed in order to keep inside of the above mentioned limit. From the tenth volume of the *Annales* those terms have been gathered which will introduce long period inequalities; they have been extended to small quantities of the fourth order. Whereas the long period inequality of Jupiter and Saturn does not occur multiplied with the first or second power of small quantities, we find in this case, terms multiplied with the first power. Indeed, the argument of the trigonometric functions which are multiplied with the factors $1/(i\,\nu' + i)$, where $\nu = n'/n$, are $3\,l' - 2\,\lambda$ or multiples of this angle. To retain all values $> 0''.1$ in the perturbations of the elements it will probably be necessary to include the principal terms of the second order of the mass of Jupiter and to investigate also the most important terms of the perturbing influence of Mars and Saturn.

RESEARCHES IN SOLAR PHYSICS.

BY GEORGE E. HALE.

Professor Hale exhibited a number of lantern slides illustrating his solar investigations.

A PHOTOGRAPHIC MERIDIAN CIRCLE.

BY F. L. O. WADSWORTH.

THE WORK OF THE CATANIA ASTROPHYSICAL OBSERVATORY.

BY A. RICCO.

The following establishments are comprised in the Observatory of Catania:

1. Astrophysical, photographic, meteorological, seismological Observatory in the City of Catania.

2. Astrophysical, meteorological, and seismological Observatory near the summit of Mount Etna (2950 meters).

3. Meteorological station on the south slope of Etna (1900 meters).

4. Network of thirty seismological stations in Sicily and the neighboring islands.

With a few exceptions, the various buildings and laboratories have been built and equipped under the supervision of the Director, Professor A. Riccò.

The work of the Observatory has been as follows:

1891. Restoration of the Mount Etna Observatory after its damage by the volcano. Preparation of rooms for meteorological instruments in the upper story of the Catania Observatory, and for seismological instruments in subterranean vaults. Mounting of the $5^{m}.50$ refractor in Catania and on Mount Etna. Investigations of the eruption of Stromboli and of the submarine eruption near Pantelleria.

1892. Beginning of daily observations and drawings of solar spots and prominences. Beginning of meteorological and seismological observations. Mounting of the photographic equatorial. Observations and drawings of planets at Catania and on Mount Etna. Studies of the great eruption of Etna.

1893. Mounting of the six-inch Cooke equatorial and the transit instrument. Beginning of astronomical photography. Attempts to photograph the solar corona in Catania and on Mount Etna. Observations of the solar eclipse of April 23. Observations of telluric lines at Catania (50 meters), Nicolosi (700 meters), and Mount Etna (2950 meters). Study of Etnean earthquakes and partial eruption.

1894. Modification of the photographic equatorial. Determination of the latitude and longitude of the Catania and Mount Etna Observatories. Attempts to photograph the solar corona in Catania and on Mount Etna with Huggins' and Hale's apparatus. Photographs of the rising sun and of clouds. Actinometric observations in

Catania and on Mount Etna. Studies of the Calabrian earthquakes.

1905. Modification of the photographic equatorial. Drawings of planets. Mounting of a great seismograph (pendulum 25 meters long, weighing 300 kg.) Geophysical studies of the Æolian Islands and of the Val di Noto earthquake.

1896. Beginning made in photographing the stars of the Catania zone (43°), previous plates having been made for the catalogue. Drawings of planets. Cartographic studies.

1897. Mounting of photographic spectroscope. Observations of eclipses of Jupiter's satellites. Photographs of the Milky Way with a Voigtländer lens. Simultaneous meteorological observations on Mount Etna (1900 meters station), at Nicolosi, at Catania, and on the seashore.

ON THE ANALYSIS OF ELECTRIC RADIATION.

BY G. F. HULL.

In attempting to analyze electric radiation by means of the two principles used in light we must bear in mind (1) that in general we need not expect dispersion of electric rays by ordinary matter, (2) that the receiver usually influences the measured wave-length and consequently affects, apparently, the radiation. Using the principle of dispersion Garbasso and Aschkinass found, by means of a prism of glass plates upon which were pasted strips of tinfoil, that the electric radiation was dispersed and concluded that rays of electric force may be considered, not necessarily as monochromatic, but, with the same justification as in the case of light, as composite. Using the principle of interference Sarasin and de la Rive found that the wave-length measured depends on the receiver, and Zehnder that rays of electric force are analyzed by a grating into a spectrum. Both results point to a complexity of electric radiation, but Bjerknes and Poincaré point out that they may be explained on the assumption that the radiation is simple and damped.

The author used an interferometer and nail receiver to analyze the radiation from spheres. The interference curve was approximately a damped cosine curve. In interpreting this curve, if the influence of the receiver on it be not considered, the conclusion is reached that the radiation is a damped sine function of the time. But it was found, using different receivers, that the form of the curve was influenced by the receiver and therefore that the latter possessed a definite period and was not dead beat. The problem is thus more complicated than the corresponding one of light. Using a number of receivers a fair approximation regarding the nature of radiation from spheres may be arrived at and the conclusion is drawn that it is less highly damped than theory leads us to believe and that it is practically simple.

THE PSYCHOLOGY OF THE PERSONAL EQUATION.

BY TRUMAN HENRY SAFFORD.

(See Science, November 26, 1897).

ON THE VARIATION OF SOLAR RADIATION.

BY FRANK W. VERY.

This paper is published in the *Astrophysical Journal,* Vol. 7, pp. 255-272.

ON THE ROTATION OF THE SUN.

BY L. E. JEWELL.

SECOND CONFERENCE

The Second Conference of astronomers and astrophysicists was held at the Harvard College Observatory, on Thursday, Friday and Saturday, August 18-20, 1898.

The selection of the Harvard Observatory as the place of this Conference had much to do with the highly successful outcome of the gathering. The hospitality of the Director, the completeness of the arrangements made by him, the constant attention of the members of the Observatory staff in showing visitors the numerous instruments and the extensive collection of celestial photographs, the opportunities afforded between sessions for the inspection of the museums and laboratories of Harvard University and of the Blue Hill Meteorological Observatory, all contributed to the success of the occasion.

At this Conference, as stated in the Introduction, preliminary steps were taken toward the establishment of the Astronomical and Astrophysical Society of America.

The following persons were in attendance at the Harvard Conference:

C. G. Abbot
W. H. Attwill
F. L. Bailey
Ruth E. Bailey
Solon I. Bailey
S. W. Balch
E. E. Barnard
L. A. Bauer
N. E. Bennett
S. H. Brackett
Annie J. Cannon
Albert P. Carman
H. H. Clayton
Henry S. Carhart
F. L. Chase
Wm. H. Collins
Mrs. Wm. H. Collins
H. R. Colson, Jr.
Geo. C. Comstock
F. H. Constant
Charles R. Cross
Herman S. Davis
Harriet R. Donaghe
A. J. Donlon
A. E. Dolbear
Charles L. Doolittle
Helen W. Doolittle
N. E. Dorsey
M. C. Douglass
H. W. DuBois
Mrs. H. W. DuBois
John A. Dunne
J. H. Earp
J. R. Eastman
Mrs. J. W. Eddy
W. S. Eichelberger
W. L. Elkin
A. P. Ferguson
R. A. Fessenden
Edward P. Fleming
Mrs. M. Fleming
Albert S. Flint

Mary B. Ford
W. S. Franklin
Edgar Frisby
Lucy A Frost
Royal H. Frost
Caroline E. Furness
Willard P. Gerrish
Edith F. Gill
H. M. Goodwin
Ida Griffiths
J. G. Hagen
George E. Hale
Asaph Hall
George G. Hall
J. P. Hall
J. N. Hart
John F. Hayford
John T. Hedrick
Lillian L. Hodgdon
G. W. Hough
W. J. Humphreys
Agnes Hyde
William Hyde
Harold Jacoby
E. S. King
Lawrence LaForge
Miss E. F. Leland
Frank H. Loud
Carl A. R. Ludin
J. W. McCoy
Alexander McFarlane
Miss A. J. McKay
C. H. McLeod
Antonia C. Maury
Albert A. Michelson
Dayton C. Miller
Edward W. Morley
J. A Mulry
G. W. Myers
Simon Newcomb
Annie E. Parkhurst
Henry M. Parkhurst
H. M. Paul
Edward C. Pickering
Mrs. Edward C. Pickering
William H. Pickering
B. O. Pierce
Charles Lane Poor
Mary Proctor
Alden W. Quimby
F. G. Radelfinger
Wm. Maxwell Reed
Charles H. Rockwell
Jonathan T. Rorer
A. Lawrence Rotch
W. C. Sabine
Charles E. St. John
F. E. Seagrove
Arthur Searle
Aaron M. Skinner
Frederick Slocum
Monroe B. Snyder
J. S. Stevens
Mabel Cushman Stevens
John Stein
John M. Stockwell
A. E Sweetland
David P. Todd
E. S. Trask
Winslow Upton
J. M. VanVleck
Frank W. Very
Robert DeC. Ward
Charles F. Warner
W. R. Warner
Theodore Waters
A. G. Webster
Oliver C. Wendell
Sarah F. Whiting
Frank P. Whitman
Mary W. Whitney
Emily Newcomb Wilson
Anna Winlock
Louisa Winlock
Miss E. G Wolffe
Miss I. E. Woods
R. S. Woodward
Paul S. Yendell

ABSTRACTS OF PAPERS

PERSONAL EQUATION IN TRANSIT OBSERVATIONS.

BY ARTHUR SEARLE.

In the study of personal equation, we learn only what may happen under special conditions, which may possibly never recur, and the labor demanded by the study often seems excessive in view of its very limited results. This furnishes an excuse for the comparatively superficial investigation of the subject ordinarily undertaken, as in the present instance. Still, some conclusions which seem worth recording have been reached by the experience obtained during the last thirty years at Harvard College Observatory. One of these conclusions is that the micrometrical determination of the collimation error of a transit instrument, by means of collimators or of meridian marks, so commonly disagrees with the result for collimation obtained by the adjustment to each other of a series of transits observed with the same instrument, that it becomes unsafe to depend upon the micrometrical determination in the reduction of observations. While the results obtained by different observers by means of the collimators agree very closely, and while the error thus determined remains nearly constant for considerable periods of time, the results obtained by the same observers from the discussion of series of transit observations give different results, which are neither so accordant nor so constant as those obtained micrometrically. It may be, of course, that the errors indicated by the transits are not really collimation errors; that is, it may be suspected that some other coefficient than the secant of the declination might be employed in the redutions to better advantage. After trial of various coefficients, however, none have been found to produce as much accordance in the results for different stars as can be obtained with the secant of the declination. It is therefore provisionally assumed that the discrepancies which have been noticed are due to a personal equation in collimation, in addition to the kind of personal equation usually recognized in transit observations, consisting simply in a difference in the absolute time of the observations made by different persons.

Another form of personal equation in transit observations occasions errors of the kind which might be attributed to a rate of the clock at the time of observation differing from the rate found for it by the comparison of the results for different days. But this supposition is excluded when we find on the same evening different rates derived from the transits observed by different persons.

It also happens that differences occur systematically between different observers with regard to stars in northern and southern declinations equally far from the equator; so that the apparent position of the axis of the instrument, as well as the line of collimation, changes with the observer. This phenomenon is more difficult to understand than those previously mentioned.

Personal equation dependent on stellar magnitude has been for some time an admitted fact, and was merely mentioned in the paper here abridged. We have, accordingly, five kinds of personal equation possible in transit observations: (1) In absolute time, (2) In collimation, (3) In the apparent position of the instrument, (4) In clock rate, (5) In the effect of stellar magnitude.

SOME INVESTIGATIONS RELATING TO ZENITH TELESCOPE LATITUDES.

BY G. C. COMSTOCK.

A series of latitude determinations by the Talcott method was undertaken by the author in the winter of 1895 for the purpose of investigating the effect of barometric and thermometric gradients in the atmosphere upon zenith telescope latitudes. The instrument employed was an excellent portable transit by Bamberg, and the observing program comprised chiefly pairs of stars culminating at large zenith distances, in the average about seventy-five degrees, since the effects sought increase with $\sec^2 z$.

The amount by which a stratum of homogeneous air was tipped from its normal horizontal position was determined for each observing night from the isobars and isotherms of the United States Weather Bureau's weather map for 8 p. m., and the resulting disturbance compared with the observed value of the latitude. During the period of observation the inclinations of the strata varied from $-0'.4$ to $+2'.2$, but no obvious relation exists between these inclinations and the observed latitudes. These latter, however, show very plainly a dependence upon the direction of the wind, being a maximum when the wind comes from the direction of the Observatory chimney, distant about thirty meters from the instrument. The amplitude of this apparent variation in the latitude is approximately one second of arc.

A similar series of observations made in the months of May and June, when the chimney was not heated, shows no such variation and also shows no marked dependence of the latitude upon the inclination of the air strata, although in this series the inclination of the strata varied from — 1′.6 to + 2′.8, and the zenith distances of the stars observed were included between 76° and 87°. Observations at this latter zenith distance, although difficult and of diminished precision, are nevertheless eminently satisfactory for the purpose in hand.

The foregoing results show that the variation from night to night in the value of the observed latitude depends upon local conditions rather than upon elements which can be read from a general weather map. That perturbing elements of appreciable magnitude are generally present in zenith telescope work, may be inferred from the following table of recent determinations of the constant of aberration made by the Talcott method, and the remainder of the paper was devoted to a discussion of the local surroundings at the several places of observation with reference to determining their probable effect upon the value of the aberration.

Place	Authority	Observed Aberration Constant		Corr.
Hong Kong	*A. N.*, 3504	20″.38	± 0″.07	?
Hong Kong	*A. N.*, 3504	20 .43	± 0 .06	?
Honolulu	*Bull. C. & G. Surv.*	20 .43	± 0 .03	—
New York	*A. J.*, 401	20 .46	± 0 .01	?
Strassburg	*V. J. S.*, 1895	20 .47	± 0 .01	?
San Francisco	*Bull. C. & G. Surv.*	20 .48	± 0 .03	—
Berlin	*A. N.*, 3015	20 .49	± 0 .02	—
Naples	*Nov. Determ.*, Fergola	20 .53	± 0 .01 (?)	—
Bethlehem	*A. J.*, 406	20 .55	± 0 .01	—
Cape	*M. N.*, Dec. 1897	20 .58	± 0 .01	—
Berlin	*A. J.*, 429	20 .61 (?)		—
Hong Kong	*A. N.*, 3504	20 .64	± 0 .08	?

This effect cannot, in any case, be determined quantitatively, but its sign is indicated in the last column of the table, a + indicating that the observed value should be increased to eliminate the effect of local conditions: e. g., at Naples the diurnal range of temperature north of the Observatory (over the land) is greater than that south of the Observatory (over the sea), whereby stars near the zenith are relatively thrown toward the north in the evening and toward the south in the morning, thus producing too great a value of the aberration. Similarly, at the other stations, an unsymmetrical diurnal variation of temperature is supposed to produce an effect upon the observed value of the aberration.

STARS OF THE FIFTH TYPE IN THE MAGELLANIC CLOUDS.

BY M. FLEMING.

Stars having spectra consisting mainly of bright lines belong to Type V. In 1891 the number of these stars known was thirty-three. Three of these were discovered by Wolf and Rayet, six by Copeland, one by Respighi, three by Pickering, and twenty from the Draper Memorial Photographs of the Harvard College Observatory. In May 1897 the number known was sixty-seven. All of these stars lie closely along the central line of the Milky Way, and, although the sky had been equally well covered with spectrum plates from pole to pole, a careful examination of these plates failed to show any of these stars outside of this region.

On May 26, 1897, an examination of two plates taken at Arequipa with the Bruce telescope, showed a group of six of these objects in the Large Magellanic Cloud. Two later plates add fifteen more in the Large Magellanic Cloud, and these, with three others in the Milky Way, and one in the Small Magellanic Cloud, make the total number of these stars, so far known, ninety-two.

Thirteen of these were found visually, all the others have been found from the photographs in the Draper Memorial work. The great advantages of photography in the study of stellar spectra are thus again demonstrated.

The presence of so many stars of the Fifth Type in the Magellanic Clouds establishes another connection between them and the Milky Way.

CLASSIFICATION OF THE SPECTRA OF VARIABLE STARS OF LONG PERIOD.

BY M. FLEMING.

In the classification of the spectra of stars in the *Draper Catalogue* the letter M was assigned to stars having spectra of the third type. Later these stars were subdivided into four groups, Ma, Mb, Mc, and Md, of which α Orionis, α Herculis, DM. — 2°3653, and o Ceti were given as examples. In the last of these stars the hydrogen lines are bright, and this spectrum has been shown to be characteristic of variable stars of long period; indeed, by this peculiarity in the spectrum about a hundred new variables have been found. A further examination of these spectra shows that they can be further subdivided into eleven groups. A classification was made from an examination of the continuous spectrum, the comparative brightness of the hydrogen lines being also carefully estimated, always assuming the brightness of $H\gamma$ as 10. The first class, of which R Lyncis is the typical star, shows a spectrum resembling α Tauri, having also $H\beta$ and $H\gamma$ strongly bright and nearly equal, while $H\delta$ is barely visible. The last group, of which R Leonis is the typical star, shows a continuous spectrum similar to DM. — 2°3653, or a little beyond that star in the classification. Of the bright hydrogen lines in R Leonis $H\beta$ is not seen, $H\gamma$ is barely visible, and $H\delta$ is strongly marked. The other classes form a nearly continuous sequence between these extremes.

VARIABLE STARS IN CLUSTERS.

BY S. I. BAILEY.

A systematic search of twenty dense globular clusters by means of photographs made with the thirteen-inch telescope gives the following results:

Number of stars examined about 18,600.

Number of variables found 501.

In certain clusters no variables have been found; in others very few. The results in four clusters are especially striking.

N.G.C. 5272, Messier 3, out of about 900 stars examined, has 132 variables, nearly fifteen per cent.: N.G.C. 5904, Messier 5, out of about 900 stars examined, has 85 variables, about 9½ per cent. In N.G.C. 7078, 51 stars out of 900, or six per cent., and in N.G.C. 5139, ω Centauri, 125 out of about 3000, or four per cent., have been found to be variable.

Considerable progress has been made in the discussion of the variables in ω Centauri. The approximate periods and light curves of 105 have been determined. The extremes periods so far found seem to be 475 days in the case of No. 2, and 6^h 11^m in that of No. 91. Ninety-eight have periods less than twenty-four hours.

These short periods are often characterized by sudden increase in brightness, brief maximum, a relatively slow decrease in brightness, and a considerable interval at or near minimum. On the other hand, in some cases the time of increase is equal to or even greater than that of decrease.

MERIDIAN OBSERVATIONS FOR STELLAR PARALLAX.

BY ALBERT S. FLINT.

The reduction of the observations made in the years 1893-96 at the Washburn Observatory, Madison, Wisconsin, of which a report was given at the conference of last October, is now nearly complete.

The Repsold meridian circle of 122 mm. aperture was employed in the well-known but comparatively new method of observing meridian transits of each parallax star with two comparison stars. The observing list of nearly one hundred stars comprised over seventy stars of large proper motion, together with binaries, most of which have considerable proper motion. Screens of fine brass wire were employed to reduce the apparent magnitudes of the brighter stars.

The reduction of the present series of parallaxes to the weighted means of good determinations by previous observers, from the thirty stars available, is 0″.03. Systematic error might be expected mostly on account of larger differences of magnitude between the parallax stars and their comparison stars. These differences range from — 2.0 to + 2.0, the latter sign indicating that the parallax star was fainter. A graphical representation of all the parallaxes shows some appearance of such an error, and it appears to be within the limit + 0″.065 for a difference of one magnitude in the positive direction. A plot of the differences from previous determinations, on the thirty stars already mentioned, gives a similar indication. This effect appears more marked in several cases which will require further investigation. Extensive observations were made concurrently with the parallax observations upon independent, miscellaneous stars employing the screens in order to control the personal equation depending upon magnitude.

A plot of the parallaxes according to the right ascensions of the stars gives no plain evidence of seasonable variation. The same holds true of the differences from previous determinations.

The general means of the probable errors of the parallaxes, from the stars most frequently observed, range from ± 0″.032 to ± 0″.045, the former value for stars of higher declination, the latter for those of moderate southern declination. The corresponding probable errors for the observed difference of right ascension of any two stars vary from ± 0″.17 to ± 0″.22. The probable error of a single observation appears not to be affected by such differences as occur in the right ascensions, declinations, or magnitudes of the stars, but is increased materially upon stars too faint for convenient observation.

A graphical representation was made of the parallaxes of the present series according to the proper motions of the stars, in all cases where they were greater than 1″ with the exception of Groombridge 1830. The plotted points happened to fall into three groups, the apparent centers of which lay on one right line. From this line the following figures for mean parallax corresponding to proper motion are derived:

Proper Motion	Parallax	Number of Stars
1″.25	0″.10	40
2 .05	0 .14	13
4 .20	0 .28	5

A new series of parallax observations by this method has been begun. The list consists of 121 parallax stars, second magnitude stars, binaries, and certain stars of large proper motion. Instead of repeating the customary method of observation, that of recording transits over a fixed reticle a Repsold transit-micrometer is employed, and the observer holds the image of a star during transit in bisection between a pair of movable threads.

THE DIRECT GRATING SPECTROSCOPE.

BY CHARLES LANE POOR.

This paper consisted of a description of a new method of using the concave grating for stellar spectroscopy. Preliminary notes, giving full details of the method in question, were published in the *Astrophysical Journal* for March 1898, and in the *Monthly Notices of the Royal Astronomical Society* for March 1898. Since these notes appeared a much larger grating was especially ruled by Professor Rowland, and this paper embodied the results obtained with this new grating. This grating has a ruled surface 5¾ x 2 inches. The radius of curvature is one meter, and the grating is ruled with 7500 lines to the inch. The definition is excellent.

Many original negatives were exhibited, as well as several enlarged glass positives. The experiments with the larger grating showed that a good photograph of the spectrum of Sirius could be obtained in the second order with an exposure of five minutes. In general, it may be stated that the time of exposure for different stars was very much less than had been currently expected.

THE EFFECT OF ATMOSPHERIC DISTURBANCE ON TELESCOPIC DEFINITION.

BY G. W. HOUGH.

During the past year a number of papers have been published showing the effect of different conditions of the atmosphere on telescopic definition. In a discussion of this nature it is important to discriminate between the effects produced by disturbances directly in front of the object-glass and those in the distant atmosphere.

A cylinder of light the size of the object-glass extends through the whole body of atmosphere, and it is extremely probable that abnormal conditions may exist at different distances from the object-glass.

In the latitude of the United States atmospheric waves are constantly propogated from west to east with a velocity of from ten to forty miles per hour. Aside from this, near the surface of the earth there is a bodily translation of air which may move in any direction. Hence it follows that at every instant the wave-front meets a new stratum of atmosphere. Now when we consider the magnitude of atmospheric waves, the area of the wave-front for the largest telescope in use will be infinitely small as compared with the area of the disturbed region, and it is reasonable to assume that the wave-fronts will be in the same condition in every part.

As every unit of surface of the object-glass forms an image at the focus, the superimposed images will be of the same nature and the primary images formed by a large object-glass or a small one, will be of the same quality.

Under this conception the disturbance in definition will depend on the magnifying power, and will be entirely independent of the size of the object-glass. This conclusion appears to be borne out by experience. When the definition is bad, reducing the aperture of the 18½-inch refractor of the Dearborn Observatory, does not materially improve the seeing, and I long ago abandoned the use of caps for this purpose.

A good deal has been written regarding the advantages of a small aperture under the condition of imperfect definition. The following considerations I think will show the fallacy of the argument.

If on a night when the definition near the zenith is at its best, and the highest power (925) of the 18½-inch refractor can be used on a double star of $0''.2$ or planetary detail studied with a power of 500, the telescope be pointed at a zenith distance of 45°, it will be seen that the definition is not as good as near the zenith. When it is pointed at 60° zenith distance, a lower magnifying power must be used to secure reasonable definition.

When we have gotten below 70° zenith distance one may do some useful work by employing a lower power, but as we approach the horizon a point will be reached where the definition is too poor for any useful work.

A six-inch object glass would be affected in the same manner, but objects below a zenith distance of 60°, where the definition was bad, which were observed with the 18½-inch, would be entirely beyond the reach of the six-inch.*

On nights when the definition is bad near the zenith, the 18½ inch can be used on objects which are beyond the reach of much smaller instruments.

Hence, under any atmospheric conditions we can see more and better with a large telescope than with a small one. The time during which a large aperture can be used to its full capacity is another question. At Chicago and Evanston the 18½-inch can be used successfully with the highest power on about 10 per cent. of the observing nights. For 50 per cent. of the time it can be used for observations beyond the reach of much smaller instruments, and in the worst condition of seeing it would not be inferior to a smaller telescope.

ON THE SPECTRA OF STARS OF SECCHI'S FOURTH TYPE.

BY GEORGE E. HALE.

An investigation of the spectra of stars of Secchi's fourth type, upon which I have been engaged, with the assistance of Mr. F. Ellerman, since the beginning of the present year, while still in its preliminary stages, has advanced far enough to yield some interesting results. The spectra of 22 stars of this class, ranging in magnitude from 5.4 to 8.2, have been photographed with the stellar spectrograph attached to the forty-inch refractor of the Yerkes Observatory. In most cases, on account of the faintness of the stars, a dispersion of one 60° prism has been used, but good photographs of the spectra of 132 and 152 Schjellerup have been obtained with three 60° prisms. The work has been confined for the most part to the region between D and *b*, where Cramer's Instantaneous Isochromatic plates have given very satisfactory results. Some photographs of the upper part of the spectrum, extending as far as λ 4450 have also been secured, and by the aid of the new "Erythro" plates the spectrum of 152 Schjellerup has been photographed in the region extending from D to $H\alpha$.

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*Vide Catalogues of double stars discovered with large apertures.

After a study of the photographs I have been led to the conclusion that the spectra of 152 Schjellerup and other stars of this class contain bright lines, in addition to the heavy bands attributed to some form of carbon and numerous dark lines. On account of Dunér's emphatically expressed disbelief in the existence of bright lines in these stars,* I have taken special pains to submit the question to a careful test. The true character of these lines seems to me to be demonstrated by the following considerations:

1. The lines are best shown on photographs taken with high dispersion (3 prisms): whereas bright spaces between dark lines would be most conspicuous with low dispersion. This photographic result is confirmed by visual observations made with the forty-inch telescope. With a small direct vision spectroscope the bright lines cannot be seen, but with a dispersion of three prisms the brightest ones have been observed without difficulty in 132 and 152 Schjellerup.
2. Widening the slit does not cause them to disappear, nor, in the case of such lines as λ 5593, does appreciably diminish the visibility.
3. The intensity of many of the bright lines in the photographs is decidedly greater than that of any part of the spectrum in their vicinity which appears to be continuous.
4. At my request the spectrum of 152 Schjellerup has been observed by Professors Keeler and Campbell with a three prism spectroscope attached to the thirty-six-inch Lick telescope. Professor Keeler reports that in his opinion "there is little doubt that the spectrum of this star contains bright lines."

The wave-lengths of about one hundred bright and dark lines bebetween b and D in the spectrum of 152 Schjellerup have been determined from measurements made on several plates. It is perhaps worthy of note that the mean wave-lengths obtained for two of the most intense bright lines, λ 5592.8 and λ 5693.4, agree very closely with the mean wave-lengths of two bright lines in the spectra of the Wolf-Rayet stars, Professor Campbell's values being λ 5593 and λ 5693. Although several other bright lines in fourth type spectra probably fall very close to Wolf-Rayet lines, it is too soon to conclude that these classes of stars are related. With this possibility in mind, however, I requested Mr. J. A. Parkhurst, who had kindly offered his services, to determine the distribution of fourth type stars with reference to the Milky Way. The results of Mr. Parkhurst's investigations indicate that stars having spectra of the fourth type exhibit a decidedly greater tendency to cluster in and near the Milky Way than any other class of stars except those of the Wolf-Rayet type.

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*Sur les Étoiles à spectres de la Troisième Classe, p. 10.

A comparison of the fourth type (III *b*) spectra with those of the third type (III *a*)* fails to show any striking similarities, though there appear to be certain resemblances, particularly in the region just below *b*, which deserve and will receive further study.

The peculiarities in the spectra of the stars 541 Birmingham (DM. + 38°3957) and DM. + 59°2810, which were recognized and discussed by Professor Dunér,* are well brought out in the photographs. It has been found possible to arrange the spectra of ten stars in a series, having at one end 155*b* Schjellerup and at the other DM. + 59°2810. The differences between contiguous spectra are in most cases very slight, though 541 Birmingham, which comes next to DM. + 59°2810, is separated by a rather wide gap from the star next above it. Schjellerup 132 comes near the middle of the series. I have as yet no evidence favorable Dunér's hypothesis that fourth type (III *b*) stars are developed from those of the second class (II *a*).

The investigations will be continued as rapidly as possible, but it is necessarily slow, as the forty-inch telescope is available for this work on but one and a half nights each week, and for the fainter stars exposures of many hours are required. Mr. F. Ellerman has had an important part in the work, as he has made many of the photographs and rendered assistance in the work, of reduction. For the last few weeks I have also had the aid of Dr. Frank Schlesinger, Research Assistant during the Summer Quarter, who has done excellent work in measuring photographs and determining wave-lengths.

PORTRAIT-LENS PHOTOGRAPHS.

BY E. E. BARNARD.

While connected with the Lick Observatory series of photographs were made of the Milky Way, the various comets, etc., with a six-inch portrait lens. Lantern slides from these pictures were projected on the screen. Some of the subjects were:

The phenomenon of the "old moon in the new moon's arms," or the earth-lit portion of the new moon. The night part of the moon, illuminated only by light reflected from the earth, was clearly shown on the photograph and the details of the lunar surface during the lunar night could be made out distinctly.

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*Photographs of the spectra of many stars of the third type were taken for this purpose.

*In his valuable memoir *Sur les Étoiles à spectres de la Troisième Classe.*

The total eclipse of the moon, September 3, 1895. These photographs were made in the hope of showing a possible lunar satellite which might at the time be outside the shadow and fully illuminated.

The photography of meteors. It was found that meteors were rather frequently caught with the photographic plate and the short focus portrait lens. Several photographs of meteor trails were shown which had been obtained at the Lick and Yerkes Observatories.

Photographs of numerous portions of the Milky Way were exhibited showing the cloud structures and the great dark rifts where the substratum of stars seemed to be breaking up. A photograph in the region of Antares seemed to show that the apparently small stars that made up the ground work of the Milky Way in this region were really comparatively small bodies, perhaps very much less than our own sun in size.

The various comets had been photographed and many extraordinary phenomena, hitherto unknown, were shown on the pictures, some of which were highly suggestive.

The peculiar phenomena shown in the tail of Swift's comet of 1892 could readily be explained by an irregular emission of matter from the nucleus, while the photographs of Brooks' comet of 1893 showed such an extraordinary condition of the tail that some outside influence seemed required to explain the phenomena. It was suggested that the tail of this comet possibly encountered some kind of resisting medium about October 21, 1893, and for some time subsequent to that date. No other explanation seemed satisfactory.

A BRIEF ACCOUNT OF THE BLUE HILL METEOROLOGICAL OBSERVATORY.

BY A. LAWRENCE ROTCH.

Although in the past meteorological observatories have been associated generally with astronomical institutions, yet this union usually is disadvantageous to the former, and the separation is now customary, especially in Europe. In the case of the Harvard and Blue Hill Observatories the circumstances favoring cooperation were exceptional. The former maintained meteorological observations in some detail, while the latter, only twelve miles distant, was admirably located and equipped for this work, which, moreover, it was desired to continue indefinitely and to publish in a permanent series. Accordingly an alliance was formed in 1887, two years after the foundation of the Blue Hill Meteorological Observatory by the writer, whereby his observations and investigations are published annually, or oftener, in the *Annals of the Astronomical Observatory of Harvard College,* at the joint expense of the College and the writer. It is expected that the two institutions will be united ultimately, and with this expectation the summit of the hill on which the Blue Hill Observatory stands has been leased for a long term of years to Harvard College. The writer, however, continues to direct the work and to defray the whole cost of maintenance. Three assistants are now employed, and the annual expense exceeds four thousand dollars.

The Blue Hill Observatory was probably the first in this country to record automatically and continuously all the meteorological elements, of which hourly values have been reduced, printed, and discussed. Local weather predictions were issued for several years until the United States Weather Bureau commenced this service in Boston in 1891. Of various investigations undertaken and published, there may be mentioned the comparison of different forms of anemometers by Mr. Fergusson: the first measurements in America of the heights and velocities of clouds by Messrs. Clayton and Fergusson in 1890-1; and the exploration of the air by means of kites, which was originated at Blue Hill in 1894. An exhaustive discussion by Mr. Clayton of all cloud observations has been published, and the international cloud measurements which were completed last year will soon be printed. At the present time the chief work, apart from the routine observations, is obtaining simultaneous records of the temperature and relative humidity of the air and the velocity of the wind at heights exceeding two miles in the free air by means of kites and near the ground. It is expected that the final discussion of the kite records will be published by the Smithsonian Institution, which has aided the investigation by a grant from the Hodgkins Fund.

PHOTOGRAPHIC RESEARCHES NEAR THE POLE OF THE HEAVENS.

BY HAROLD JACOBY.

If a series of short exposures be made with a photographic telescope pointed at the pole of the heavens, we obtain a negative on which each star gives a series of dots lying approximately in a circular arc corresponding to the diurnal motion. The common center of all such arcs will be the point on the negative representing the pole of the sky. It is evident that photographs of this kind furnish a method of determining the place of the pole with respect to the surrounding stars at the time the negative was made. Moreover, by the intercomparison of the results obtainable from plates made on different dates, it is possible to arrive at a determination of the fundamental constants of stellar astronomy.

The method possesses the advantage of being entirely different in principle from those hitherto in use, and as it promises high precision, it may serve to obtain a useful check upon existing results. The first attempts to use the method practically were made, I believe, at the Harvard College Observatory, by Professor E. C. Pickering, some years ago. The present paper contains, however, the first approximately complete discussion of exact measurements upon plates of this kind. The negatives employed were made at Helsingfors by Professor Anders Donner for the writer. The Observatory of Helsingfors possesses the advantage of being the most northerly of existing observatories provided with adequate photographic telescopes. Photographs of the pole made at Helsingfors are therefore less distorted by refraction than those made elsewhere on account of the greater altitude of the pole at that place. The elimination of refraction effects by computation constitutes one of the greatest difficulties with which the writer has had to contend, so that the importance of a high latitude for researches of this kind is very evident.

The results here presented consist of:

1. The deduction of formulas suitable for the complete reduction of ordinary polar star photographs, as well as the special kind of plates just described.

2. An application of the formulas to measures on one plate of six images of each of ten stars, or sixty images in all.

While no entirely definite conclusions can be drawn from material so scanty, enough has been done to show that the new method merits the serious consideration of astronomers. It is the intention of the Columbia Observatory to extend the work so as to include the complete measurement of all the images on two Helsingfors plates made six months apart. A tentative determination of the constant of aberration should thus be possible, and should throw much light on the possibilities of the new method. The details of the work so far occomplished cannot be summarized in this brief notice, but an extended paper is in the hands of the printer, and will, it is hoped, soon be laid before astronomers.

PROPOSED CATALOGUE OF NORTH POLAR DISTANCES.

BY J. F. HAYFORD.

The United States Coast and Geodetic Survey has made it its uniform practice to make careful computations of the mean north polar distances of all stars observed for latitude with the zenith telescope. It is now proposed to publish in the near future the accumulated results of these years of computation in the form of a star catalogue.

The catalogue will comprise about 3500 stars, all brighter than the seventh magnitude. The computations have been made substantially upon the Boss system—the weights and systematic corrections of that system as published in the *Northern Boundary Report* being used for the catalogues there given and supplemented by special investigations for later catalogues.

In most of the later computations both the polar distance and proper motion have been derived by the method of least squares and the probable error of each will be given in the catalogue.

THE K LINES IN BETA AURIGAE.

BY ANTONIA C. MAURY.

A series of two hundred photographs of the spectroscopic binary β Aurigae, obtained at Harvard Observatory in the work of the *Henry Draper Memorial,* from 1889 to 1898, shows a periodic change in the intensity of the K lines in the combined spectra. A detailed examination of the plates shows that the relative intensity of the K lines of the component stars is reversed each year as compared with the year preceding.

The components of β Aurigae are probably nearly or quite equal in mass, and their spectra are closely similar. The most probable theory would seem to be that the revolving stars induce in one another reciprocal variability. If the period of this variability be two years it would represent about 180 revolutions. The components are conjectured to have each a probable mass of 1.25 times that of the sun, and the probable distance between their centers being only about eight million miles, their influence on one another, electromagnetic or tidal, might be very great. (*Cf. Astrophysical Journal,* Vol. VIII, p. 173).

THE VARIABLE STAR U PEGASI.

BY G. W. MYERS.

U Pegasi is a member of the β Lyrae class of variables. This investigation includes a comparison of the observed and theoretical light curves. The author regards the following results as pretty clearly indicated:

1. The light curve of U Pegasi is satisfactorily represented by the satellite theory.
2. The distance of centers does not differ materially from the sum of the radii of the components, suggesting the probable existence of Poincaré's apiodal form.
3. The smaller companion is about 0.77 as bright as the larger, and the ratio of the radii is approximately 1 : 0.78.
4. The inclination of the orbit is very nearly 90°, and the disk of one or both bodies, if separate, is slightly flattened.
5. The accuracy of present observations does not suffice to determine the elements of the system completely.
6. The form of the light curve near minima fails to confirm one's first impression on examining the curve, viz., that the components are separated enough to remain apart for an appreciable time at the maxima. (*Cf. Astrophysical Journal,* Vol. VIII, p. 163-172).

THE ZODIACAL LIGHT.

BY ARTHUR SEARLE.

Fifty years ago, and indeed until within ten or twelve years of the present time, all hypotheses relating to the origin of the zodiacal light were opposed by difficulties which could not be satisfactorily met. The recent progress of our knowledge upon the subject consists chiefly in the removal of the difficulties attending one hypothesis—that which assumes the light to be reflected from meteoric dust forming a part of the solar system. At present, therefore, this hypothesis tends more and more to prevail. It is true that the two principal observers of the zodiacal light, Jones and Heis, were inclined to regard it as a ring encircling the earth. The obvious objections to this hypothesis are the considerable extent of the light in latitude, which would require the supposed ring to be very near us, and the absence, at the same time, of any decided parallax, or of any obscuration by the shadow of the earth. The hypothesis, apparently, was suggested by the observations which tended to show that the zodiacal light forms a continuous belt all along the zodiac, with a slight maximum of brightness, commonly called the Gegenschein, in opposition to the sun. This maximum was the chief difficulty in the way of the meteoric hypothesis now prevalent, for, according to Lambert's theory of phases, which had acquired a ficticious authority by long usage, no such maximum should exist. But accurate photometric observation of asteroids in recent times has made it clear that Lambert's theory is wholly inapplicable to their phases, and if we suppose that meteors have phases like those of the asteroids, it appears that light reflected from such bodies should exhibit a maximum at opposition.

Since the time of Jones and Heis, observation of the zodiacal light, in its ordinary and conspicuous form, has been greatly neglected. On the other hand, we have numerous recent observations of the Gegenschein, and some which were undertaken in 1893, to be made as nearly as possible simultaneously at widely separated stations, formed a principal subject of the paper of which this is an abstract. It was concluded from the comparison of nearly simultaneous observations made in New England, in California, and in Peru, that no effect of parallax in the observed object could be detected.

Another subject of the paper was the bands permanently visible in and near the zodiac, and probably due to aggregations of faint stars or of nebulous matter, which tend to interfere with exact observation of the fainter portions of the zodiacal light, including the Gegenschein. Simultaneous and careful drawings of these bands were made by two observers during 1893 and 1895, and plates showing specimens of these drawings were laid before the audience. It appeared from these plates that the agreement between the two observers was sufficient to encourage the belief that the drawings represent real objects, which should be carefully studied by all those who desire to add to our knowledge with regard to the zodiacal light.

ROTATION OF ASTEROIDS.

BY HENRY M. PARKHURST.

The suggestion that if the asteroids were observed photometrically there might be a discrepancy arising from a difference in the reflection from the opposite sides of an asteroid, presented to us at different times in consequence of their rotation, did not originate with me. Prior to my observations discrepancies in the observations had been attributed to this cause as a probable explanation. In the first year of my observation of asteroids, 1887, I found discrepant observations of two asteroids, Nos. 40 and 42, which seemed to me to indicate their probable rotation. There were twelve asteroids more fully observed which showed no such difference. In the following year, 1888, I observed No. 40 much more thoroughly and demonstrated to my satisfaction that no such variation as I had suspected existed in its light. During 1888 and 1889, the number of asteroids which I observed was more than doubled, and no additional asteroid was suspected of such variation. It has not been practicable for me to take up the remaining asteroid, No. 42, until June of the present year. I have now observed it anew, with the result that no such variation appears. Furthermore, upon revising the observations of No. 42 in 1887, by the aid of the constants obtained from the more extended observations of the present year, the hypothesis of rotation is contradicted by those very observations of 1887.

Of course I can not prove a negative; it is not impossible that some asteroid does exist, observation of which would show large variation from rotation; but all my evidence having been demonstrated to be illusive, and the observation of many new asteroids not yet furnishing additional evidence of it, I think it is safe to dismiss the theory of a photometric change from rotation from further consideration.

REMARKS REGARDING THE PARALLAXES OF 61^1 AND 62^2 CYGNI AND THE PROBABLE PHYSICAL CONNECTION OF THE TWO STARS.

BY HERMAN S. DAVIS.

In *Contribution* 13 from the Observatory of Columbia University a discussion of the measures of certain photographic plates, made by Dr. Rutherfurd in 1871-1874 for the determination of the parallax of 61 Cygni, has been presented by the writer, to whom the measures were entrusted for that purpose by Professor J. K. Rees, Director of the Observatory.

The main result given in that publication is summarized by the lines:

Parallax of 61^1 Cygni $= + 0''.360 \pm 0''.015$.
Parallax of 61^2 Cygni $= + 0\ .288 \pm 0\ .028$.

The object of the paper prepared for the Astronomical Conference was to suggest what these results signify.

In the first place, consideration was made of whether these two stars are only optically double or are physically connected, forming a binary system. This is a question which has adherents on each side, some claiming that the variations of measures of distance, from Piazzi's time to the present, show an orbital motion; others claiming that such variations are due to accidental or systematic errors of observation. But it was pointed out that the theory of probabilities has been used somewhat more effectively in favor of orbital motion than has been the better established theory of motion of matter acted on by gravitation. Thus, too often, have claimants of rectilinear motion been met by the statement that whether the *measures* are conclusive or not, the *chances* are many millions to one against two stars of such unusual proper motion being placed accidentally in such close juxtaposition in the line of sight from the earth at this particular age in the earth's history.

Then were quoted the conclusions arrived at by Wilhelm Struve regarding the probability of their binary character. The "reasoning in a circle" by Otto Struve from the conclusion of his father back to his hypothesis was used to show that beliefs regarding this matter are based sometimes more on tradition than on logic. And the Spitaler and Zona comets of 1890 were instanced (by the quoting of Professor Barnard in *Sidereal Messenger,* Vol. 10, p. 18) to show how facts sometimes overrule probabilities. Other arguments were also adduced for the purpose of removing many of the traditional beliefs now existing concerning these stars.

While facts are more convincing than probabilities, so also are measures as convincing as logic. It was interesting, therefore, to note that the measures made by Professor Wilsing at Potsdam as discussed by the writer likewise seem to confirm the results deduced from the Rutherfurd plates. This new discussion, given in *Contribution* 13, shows a difference of parallax.

$$(61^1 \text{ Cygni} - 61^2 \text{ Cygni}) = +0''.088 \pm 0''.012.$$

The mean of previous determinations of the parallax of each of these stars gives also a difference of:

$$(61^1 \text{ Cygni} - 61^2 \text{ Cygni}) = +0''.082 \pm 0''.013.$$

While admitting, therefore, the great need of further observations, and not denying the possibility of Professor Wilsing's hypothesis that 61^1Cygni may have a dark companion, it seems that the evidence at present available leaves little room for doubt as to the existence of the difference of parallax detected by the measures of the Rutherfurd plates. And since it is the well-accepted policy of scientific investigators to accept provisionally as true, until disproved (if such should be its ultimate fate), that which has the greatest direct evidence in its favor, we are called upon to believe that the two stars of 61 Cygni are too remote from each other to form a binary system. But it is much to be desired that more evidence shall be accumulated either to verify or disprove this conclusion, and thereby throw more light upon the mystery of these interesting, because troublesome stars.

THE PROBABLE RANGE OF TEMPERATURE OF THE MOON.

BY FRANK W. VERY.

This paper is printed in *Astrophysical Journal,* Vol. VIII, pp. 199-217.

THE DOUBLE STAR WORK OF THE FLOWER OBSERVATORY, UNIVERSITY OF PENNSYLVANIA.

BY C. L. DOOLITTLE.

The object of this communication is to call attention to the performance of the eighteen-inch equatorial of this Observatory. While there are in this country a number of larger instruments by Alvan Clark & Sons this is the largest so far attempted by Brashear.

The atmospheric conditions probably differ little from those of at other points east of the Allegheny Mountains. The diffraction rings are not often seen, in fact on only one occasion has an entirely satisfactory view of these been had. They were then clearly defined and symmetrically arranged, showing that their customary absence is due to no fault of the glass.

The list of stars observed has been arranged by Mr. Burnham, and included a considerable number of difficult objects.

First will be mentioned very close pairs, not very unequal in magnitude, furnishing a test of the separating power; this, for an aperture of eighteen inches, is 0″.275 by Dawes' formula. A small list of stars of distance 0″.5 and less follows: These have been clearly separated and measured.

Star	α			δ		ρ	θ	Mags
β 232	0^{h}	43^{m}	38^{s}	49°	59′	0″.30	326°	8–8
A.C. 13	1	1	59	44	34	0 .35	250	8–8
β 1017	6	6	28	— 2	56	0 .50	160	8–9
OΣ 234	11	25	24	41	50	0 .30	140	7–8
OΣ 269	13	28	18	35	46	0 .35	224	7·3–7·7
β 939	14	7	48	— 7	58	0 .50	146	8–8
Σ 1879	14	40	23	10	10	0 .50	145	8–9
OΣ 285	14	41	42	42	48	0 .30	130	7.5–7.6
η Cor. Bor.	15	19	6	30	39	0 .44	327	6–6
Δ 15	16	40	12	43	42	0 .40	340	8–8
β 814	16	23	9	40	9	0 .24	320	8+–8+
β 631	17	33	47	— 0	35	0 .40	60	7–7
OΣ 337	17	44	46	7	16	0 .40	32	7–8
β 671	20	29	34	62	3	0 .50	330	8–10
β 155	20	47	25	50	38	0 .50	37	7½–8

Second—Close, faint companions to bright stars. These afford a test of the condition of the atmosphere rather than of the telescope. Usually the blurring of the bright star renders a critical test of the glass impossible.

Among other pairs of this class the following have been satisfactorily measured:

Star	α	δ	ρ	θ	Mags.
O Σ 38	1^h 57^m 48^s	41° 51′	0″.40	120°	5½–7
Σ 1306	8 59 48	67 37	1 .3	210	5–8.2
O Σ 235	11 26 42	61 38	0 .70	98	6–8
Σ 1768	13 33 0	36 48	1 .1	133	5–8½
β 616	14 27 15	38 50	28 .	100	4–12
μ^2 Bootis	15 20 42	37 43	0 .85	80	6½–8
β 1251	17 36 55	16 2	1 .2	70	5.8–10
β 954	16 50 59	18 38	2 .5	178	5–12
β 151	20 32 54	14 15	0 .7	359	4–6
β 733	23 56 54	26 34	0 .7	223	6–10

Third—Excessively faint stars. Among Burnham's measures with the 18½-inch Clark glass of the Dearborn Observatory are found a number of stars marked 16-14 magnitude. The note "excessively faint" accompanies most of these. In one case is a star whose magnitude is given as 14 which was not measured at all (β 639).

In case of all these pairs where the attempt has been made, including the last mentioned, it has been found practicable to obtain satisfactory measurements.

The measurements at the Flower Observatory were all made by Mr. Eric Doolittle, who has had no previous experience in this class of work. Yet he has been able to see and measure objects as faint as those which so experienced and skillful observer as Mr. Burnham could reach with the slightly larger Dearborn glass.

No effort has been made to find new pairs, but a number have been picked up in connection with the regular work.

The following are believed to be new:

Star	α	δ	ρ	θ	Mags.	Remarks
1	0^h 4^m 33^s	57° 8′	1″	285°	8.8–10.5	Near K_1
2	6 10 6	— 4 52	4½	243	6 –11	
3	6 50	56 42	4	328	9.5–10	
4	8 40	56 38	6½	120	9 –11.5	AB
			40	242	12	AC
5	9 43	58 45	1 .8	37	9 – 9.4	
Σ 1775	13 37 18	— 3 40	39	178.5	13.5	AC
β 33	15 24 42	—12 35	32	132	11.5	AE
8	21 23	59 34	7	115	9 – 9.5	
9	21 31	59 11	2	127	8.5– 8.8	
10	21 33	58 22	10	162	9.5–10	
11	21 37	57 43	3	40	9 –11.5	
12	22 26 30	55 49	3	330	10.8–11	
13	22 27 30	56 21	1 .4	45	9½–10½	
14	22 28 30	56 31	3	235	9.8–11	

We expect soon to publish the observations made during the past eighteen months, embracing about five hundred pairs.

THE POSITION OF THE AREQUIPA STATION OF THE HARVARD COLLEGE OBSERVATORY.

BY WINSLOW UPTON.

During a temporary residence at Arequipa, through the kindness of Professor Pickering and of Professor and Mrs. Bailey, the latitude and longitude of the station were determined. The chief instrument available was the special transit instrument devised for use in the prime vertical by the late Professor W. A. Rogers and described at the meeting of the American Association for the Advancement of Science in 1892. This instrument could not be adapted to use as a zenith telescope, but proved a very excellent instrument in the prime vertical. Two of Bessel's methods were employed, and the result is

$$\phi = -\ 16^\circ\ 22'\ 28''.0 \pm 0''.19.$$

The longitude was obtained by telegraph with a temporary station at Arica, Chili, whose longitude had been determined by officers of the United States Navy in 1883. Their determination of the longitude of Arica was part of an extensive series of longitudes on the west coast of South America through the coast cables. Considerable difficulty was found in getting telegraphic connection between Arequipa and Arica, though there is a land line between the two places, which, however, is never used for through messages. It became necessary to use the land line to the seaport Mollendo and to repeat the signal by cable between Mollendo and Arica. Communication was made in this way on seven nights, and proper precautions taken to insure the elimination of the errors of transmission. The result is

$$\Delta\lambda,\ \text{Arequipa—Arica},\ = +4^{m}\ 51^{s}.81 \pm 0^{s}.032.$$

Assuming the longitude of Arica to be $4^{h}\ 41^{m}\ 19^{s}.90$ the longitude of Arequipa is

$$4^{h}\ \ 46^{m}\ \ 11^{s}.71\ \text{West of Greenwich.}$$

RECENT BOLOGRAPHIC RESULTS FROM THE ASTROPHYSICAL OBSERVATORY AT WASHINGTON.

BY C. G. ABBOTT.

In his absence Secretary Langley authorizes me to state, on behalf of the Astrophysical Observatory at Washington, something with reference to the recent results derived at that Observatory in the bolometric investigation of the infra-red solar spectrum.

By the use of the bolographic method devised by Dr. Langley and developed at this Observatory there have now been found over seven hundred absorption lines in the solar spectrum between wave-lengths μ 0.76 and μ 6.0. Of these more than two-thirds have been added in the last eight months, owing to the use of several new pieces of apparatus lately obtained.

It will be recalled that this method essentially consists in the automatic production of an energy curve, in which abscissae correspond to prismatic deviations and ordinates to energy of radiation in the spectrum. Indentations in this curve indicate diminution of energy due to absorption, either from the sun's gaseous envelope or our atmosphere, and thus give the position of Fraunhofer lines.

It will be readily understood that attention must be paid to exclude errors from the introduction of deflections due to tremor of the ground, fluctuations of the electric current, and to other causes. These are in practice reduced to the smallest possible magnitudes, and such as remain (being variable in place and form) are eliminated from the final results through a comparison and measurement of six or more plates. Such a reduction as this is very arduous, and, in the case of the present results, has entailed about forty-four thousand separate comparator observations. The accuracy of the mechanical devices by which the abscissae of the bolographs are governed is extreme, and it is largely due to this that the final values of deviation are not usually in error (in so far as dependent on the bolographic processes) by as much as a second of arc.

The abscissae of the bolographs, giving as they do the accurate position of the absorption lines, are naturally of the first importance in the present work; but the ordinates, corresponding to intensity of radiant energy, are by no means lost sight of. Indeed, at several regions in the infra-red spectrum there have lately been noticed very marked changes in the absorption. It appears, for instance, that for three months of the year, which are (fortuitously or otherwise) the months in which the foliage is put forth, there is a very noticeable decrease in the absorption on the long wave-length side of the band at about μ 1.4, called here ψ. Paschen has found this band to be caused by water vapor. If the absorption in the portion affected was due to carbonic acid gas perhaps the phenomenon might be accounted for by the vegetable growth as above hinted.

To illustrate the general form of the energy curve, as well as the agreement between successive bolographs, two superposed curves extending from the F line in the green to the great absorption band Y at about μ 4.2 were presented. These curves are given on a background of plotting paper whose intervals (reduced in the same ratio as the curves) were originally centimeters, and correspond each to 4′

of arc deviation. At one point between F and D one curve was intentionally shifted in the making, as it was feared to be too near the edge of the photographic plate. The scale of ordinates was altered at three points by changing the slit width. From F to near C it is 1.00; from this point to below A it is 0.50; from this point to X it is 0.20, and from this point to the close, 1.00. Such curves as these show in the original some two hundred "real" deflections. In detail work the scale of deviations is spread out four times, the plate is moved much slower, and as a consequence, many small deflections here rushed over and obliterated are brought out.

THE DISTORTION OF PHOTOGRAPHS MADE WITH THE BRUCE 24-INCH PHOTOGRAPHIC TELESCOPE.

BY H. H. TURNER.

A letter was read from Professor H. H. Turner, University Observatory, Oxford, England, giving the provisional results of measurements of a plate taken with the Bruce twenty-four-inch photographic telescope in order to determine the distortion, if any. His conclusions are:

"First—The optical distortion on the plate is quite small, if existent, up to three degrees from the center, and perhaps further; that is, the star images are truly projected on a tangent plane with considerable exactness. I have not yet detected any *radial* displacement, though there seems to be a small term depending upon the product xy indicating a sort of *strain* of the field.

"Second—Whatever may be the ultimate definite result as regards optical distortion, your plates will give (by due allowance for such distortion which will be quite easy) as good places as we are getting on the plates for the Astrophotographic Catalogue. The images are perhaps a little larger and more diffused, but are quite easy to measure. This holds for certainly 4° x 4° and probably further.

"Third—If I am right in believing that fear of optical distortion was the motive for rejecting the photographic doublet, the above conclusions show this fear to have been groundless, and the manifest advantages of getting a large field at once prove the doublet to be the right instrument—certainly for charting purposes."

ON A PRACTICAL METHOD OF PHOTOGRAPHING THE SPECTRUM OF THE CORONA IN NUMEROUS DISTINCT REGIONS.

BY DAVID P. TODD.

Recent research on the corona indicates that it is a composite of a triple system of rays or streamers. But it is not known whether the filaments of these systems have the same origin or not. Perhaps the only conclusive method of testing this important question is that of a multiple spectroscope, in which slits are arranged tangentially at both extremities of equatorial and polar diameters; also radially, or approximately so, along the lines of expected streamers. It is proposed to bring the spectra of at least four separate inner coronal regions on a single plate, and of four outer areas on another plate. All on a given plate will therefore have the same exposure and development, and will be approximately comparable. A two-inch image with large aperture will be requisite; and the varying lengths of exposure, together with a maximum number of plates, are easily secured by means of the automatic apparatus of the Japan expedition of 1896.

ON AN EFFECTIVE INSULATION OF MERCURIAL HORIZONS.

BY DAVID P. TODD.

In regions of frequent and violent seismic disturbance, like Japan, it is well known that shocks which are very destructive at lower levels on the plains, may often fail to be felt in the mountains surrounding them. The reason for this is not difficult to see: as the origin of the earthquake wave is submarine, the vibrations, which readily propagate themselves through the relatively small masses of earth in the plain, become dissipated by inertia of the vaster masses of outlying mountains. Application of this principle to the insulation of a support for a mercurial horizon has led to complete success in checking the tiny undulations of its surface which destroy its capacity for specular reflection. First a zenith collimator of the ordinary type was constructed, in which the reflected reticle was perfectly visible in a collimating eyepiece. Then several slabs of marble or granite, about three inches thick and a yard square were provided; the number requisite will vary with the degree of disturbance to be overcome, and the perfection of insulation sought. Practically, five or six will be sufficient. They are laid up horizontally, as in stata, but separated from each other by wave-checking material, inserted at three points between each two slabs. Practically, tufts of any material suitable for the ordinary mattress serves this purpose well; but I have obtained the best results by the use of cork dust in small, tightly stuffed bags. The top slab of the series is made of three or four times the thickness of the intermediate ones, and surmounted on this is the zenith collimator. Of course the slightest touch of the finger on the topmost slab will cause the reflected reticle to disappear; but a nadir observation is wholly secure against interruption by passing freight trains and trolley cars, although in close proximity.

ON THE FOUNDING OF ASTRONOMICAL AND OTHER INSTRUMENTS OF PRECISION.

BY DAVID P. TODD.

All astronomical and physical instruments work best when provided with (1) an absolutely stable foundation, and (2) a perfectly rigid mounting. These ideal conditions can only be reached approximately. In my experience the first is more often secured than the second. The object of this paper is to show how rigidity of mounting may be secured equally with stability of foundation. This means, of course, a welding or union of foundation and mounting into one. If it is convenient or practicable to build the mounting very massive. gravity alone may make this union sufficiently effective, provided that ordinary care is exercised in making the junction at three points only. But in many classes of instruments, massiveness of mounting is wholly impracticable. Eclipse instruments especially belong to this category; they must be light in order to be easy of transportation. but rigidity is equally essential for perfect definition of photographs of the solar corona. As a result of several years' study of this problem, in connection with preparation for several expeditions, I have finally reached a satisfactory construction for effecting a union of mounting and foundation, which appears applicable to instruments in observatories as well. Simply stated, it is a method by which the mounting is enabled to secure a permanent grasp upon many tons of earth underneath it. First, three holes are dug, as if for setting the posts of a fence; their distance apart is regulated by the area desirable to include as the base of the instrument. Into these holes were set three wrought-iron pipes, about five feet long and three inches in diameter; perhaps two feet of each pipe being left projecting above the surface of the ground. To the bottom of each pipe was screwed a projecting flange, and the hole around both pipe and flange was filled about a foot deep with cement and gravel, thoroughly rammed into position and allowed to harden. The remainder of the holes were then filled as was most convenient. The second point of construction was met by placing three stout timbers or pipes horizontally between the vertical pillars. These were forced into position close to the ground, and spread the pier pipes a trifle outward. Through holes bored near the top of the pier pipes, long rods or bolts were then run, parallel to the timbers below them, thus forming the third essential of the mechanical construction. By tightening up these bolts in the ordinary way, the tendency was to spread the cement bases of the piers outward. But these would yield only slightly, and any degree of tension could be secured by means of the bolts. This highly portable form of mounting was devised and first employed for three mountings for the photographic instruments of the Amherst Eclipse Expedition of 1896, equipped by the liberality of Mr. D. Willis James, of New York, and sent out to Japan in his yacht "Coronet." Such a mounting admits of the most rapid installation, and furnishes a degree of rigidity unusual in the ordinary types.

RESULTS OF HELIOMETER OBSERVATIONS ON THE REFRACTION OF RED STARS.

BY F. L. CHASE.

SWIFT'S COMET, 1892 I.

BY W. H. PICKERING.

Professor William H. Pickering presented a paper on Swift's Comet, 1892 I. This comet, discovered March 6, was first noticed to have a faint tail, by Finlay, on March 26. As discovered at Arequipa March 29, the tail was well developed. Forty-four photographs were taken of this and used in a recent investigation of its nature. The tail was plainly twofold in character, the inner tail continuously issuing from the head, and, being at least twenty degrees in length a month after passing perihelion, consisted of two absolutely straight rays inclined at an angle of ten degrees. The outer tail was formed of successive eruptions from the head, later diminishing in angle. The whole effect was to produce multiple tails like the comet of 1744. The photographs showed the inner tail to be of a different character on alternate days, now appearing continuous near the head, and now bifurcated. The explanation is that the comet rotated about a longitudinal axis directed toward the sun, the rotation period determined being 94.4 hours. The period was determined by the use of photographs of Professors Barnard and Wolf, and those made at Arequipa by the writer. Bessel observed in Halley's comet, in 1835, "a vibration from side to side," with a period of 110 hours; this was probably a similar rotation of the comet with an analogous period. The changing appearance of both comets being explicable by the hypothesis of rotation, the next endeavor was to find a physical explanation of the cause of such rotation. The sun furnishes a strong electro-magnetic field, the comet also, by the electrical induction of the sun, receives electrical charges, and these charges are, by the gases of the tail, radially projected from the head of the comet, and become in effect so many electrical currents. The result of the motion of these radiating currents, *i. e.,* tails in the magnetic field of the sun, is the production of a spinning of the comet about a longitudinal axis. Theory would thus produce the rotation demanded by observation, and the rotation would be independent of the direction of motion of the comet, but north of the solar equator the rotational force is in one direction, and south of it in the other.

It is generally impossible to indicate a point in the tail of the comet; the exception occurs in the plates of April 6, 7, 8, and 10, where a bright detailed structure is receding with increasing velocity of from one million to twenty-five million kilometers per day. The velocity of recession is thirty-six times the acceleration of gravity, and does not agree with any of the velocities required by Bredichin's hypothesis. The spectrum as given by the objective prism, of the head and tail, showed five bands probably due to hydrocarbons. A further test of the theory of axial rotation of comets near the sun would be an observed change of direction or speed of rotation in the solar magnetic field. Another would be the observation of the rotation when the tail is directed approximately toward the observer.

THIRD CONFERENCE OR FIRST MEETING

The third Conference of Astronomers and Astrophysicists was held at the Yerkes Observatory, on Wednesday, Thursday and Friday, September 6-8, 1899, in accordance with arrangements made by the committee appointed at the Second Conference. This committee had been authorized to prepare a constitution and arrange for the organization of a permanent society. At the second session the constitution was adopted, substantially in the form presented by the committee and as printed elsewhere in this volume, and at the last session, on September 8, the organization was completed by the election of officers as follows:

President	Simon Newcomb
First Vice-President	Charles A. Young
Second Vice-President	George E. Hale
Secretary	George C. Comstock
Treasurer	C. L. Doolittle
Councilors for two years	Edward C. Pickering James E. Keeler
Councilors for one year	Edward W. Morley Ormond Stone

Professor Comstock announced that, owing to poor health, he would not be able to undertake immediately the active discharge of the duties of Secretary, and by common consent Professor E. B. Frost was designated as Acting Secretary for one year.

The committee on the total solar eclipse of May 28, 1900, appointed at the preceding conference, and consisting of Professors Newcomb, Hale, Barnard and Campbell, presented a preliminary report in which it was stated that the aim of the committee had been:

1. To ascertain the opinion of astronomers regarding the best means of securing cooperation, the most important classes of observations and the best means of securing them, and the plans of the various eclipse parties.

2. To collect other information likely to be useful to persons planning to observe the eclipse.

For the purpose of securing information the committee addressed a circular letter to American astronomers, and from the replies received, it was concluded that the eclipse would be extensively observed, with an effective distribution of stations along the line of totality, that a great variety of observations would be made, including studies of the minute structure of the corona, both visually and photographically, photography of the flash spectrum, determination of the wave-length of the green coronal line, measurement of the heat radiation of the corona, photographic search for intra-mercurial planets, etc.

The report was accompanied by extracts from letters received from a number of astronomers. (Cf. *Astrophysical Journal,* Vol. X, pp. 215-219).

The committee on the United States Naval Observatory, appointed at the second conference, reported that the opinions of astronomers regarding the organization of the Naval Observatory had been obtained and communicated to the Secretary of the Navy. In harmony with the suggestion of the committee, the Secretary of the Navy, with the advice and approval of the Superintendent of the Observatory, had appointed a Board of Visitors to visit, examine and report upon the United States Naval Observatory. This Board consisted of Hon. William E. Chandler, chairman; Professor George C. Comstock, secretary; Hon. A. G. Dayton, Professor E. C. Pickering, and Professor George E. Hale.

The third conference was attended by about fifty astronomers and astrophysicists, from all parts of the country. Like the preceding conferences it was a gathering of great interest to those who were present. Professor William Harkness, then director of the United States Naval Observatory, presided over the sessions.

ABSTRACTS OF PAPERS

POSITION OF THE POLAR AXIS AND THE FLATTENING OF NEPTUNE FROM THE CHANGES IN THE ORBIT OF ITS SATELLITE.

BY S. J. BROWN.

The large changes which had been observed in the longitude of the node and the inclination of the orbit plane of Neptune's satellite referred to the earth's equator were explained by Tisserand on the assumption of only a moderate polar compression of the planet. The orbits based upon the measures of Professors Newcomb, Hall, Holden, Hermann Struve, and A. Hall, Jr., were best satisfied by a uniform, progressive change of the above elements. From a series of observations by Barnard in 1897-98, and another by himself, the author has been enabled to show that there is a variation in the rate of this change. The result of a least square solution from all the available elements from 1848 to 1898 was given in a table. Although the residuals are but slightly smaller than would result from the assumption of a uniform rate, this is chiefly due to the inaccuracy of the earlier elements. The validity of a variable rate is further confirmed by an apparent increase in the mean motion of the satellite referred to the movable node of the orbit plane on the earth's equator, which is otherwise difficult to explain. The equatorial protuberance of the planet will cause the pole of the satellite's orbit to describe, with uniform retrograde motion, a small circle around the pole of the planet's equator considered as a fixed point, while the inclination of the two planes will remain constant. The node of the satellite's orbit on the planet's equator will thus move uniformly along the latter, in a direction contrary to the motion of the satellite. The differential equations of this motion were given.

A least square solution of thirty-six equations of condition gave the following elements of the planet's equator:

$$\left.\begin{array}{r@{\;=\;}l} \gamma & 17^\circ.84 \\ I_0 & 49\ .38 \\ \theta_0 & 119\ .16 \\ N_0 & 22\ .02 \end{array}\right\}\text{Equator of 1850.0}$$

$$\Delta\theta = 0\ .677$$

The flattening is $\epsilon = 1/102.2$.

The period of the revolution of the pole of the satellite's orbit is 531.75 years. The flattening is a quantity represented by a difference of only $0''.03$ between the polar and equatorial diameters of the planet—a quantity scarcely measurable in the most powerful telescope.

(Published in the *Astronomical Journal*, No. 479).

THE REPSOLD TRANSIT MICROMETER OF THE WASHBURN OBSERVATORY AND SLAT SCREEN APPARATUS.

BY A. S. FLINT.

The transit micrometer is at present employed on the meridian circle, of 12.2 cm. aperture, in a new series of observations for stellar parallaxes by the method of meridian transits. The essential feature of this instrument is an auxiliary screw which is geared with the regular right ascension screw and carries the eye-piece to follow the movable thread. The observer keeps a star image bisected continuously by means of two turning heads on this auxiliary screw, one on each side of the micrometer box, while a series of contact points on the head of the right ascension screw effect the electric signals on the chronograph. The present observer finds the probable error of a single signal to be 0.030s., the same as in the ordinary method with fixed threads.

This micrometer has also a device for obtaining a record of several bisections on a given star in declination without the necessity of reading the micrometer head. A lever clamped to the declination screw travels over a short graduated arc and, being pressed down by the observer, pricks a mark on a strip of paper.

Some suggestions were made for minor improvements, but the performance of the micrometer as a whole has been found very satisfactory.

The slat screen apparatus, designed by Professor Comstock, is intended to furnish the simplest means of diminishing the apparent magnitude of the brighter stars. A frame clamped to the objective end of the telescope bears a series of five slats, each 25 mm. wide, in front of the objective. These slats rotate about their longitudinal axes and are so connected as to turn together by means of a wire cord passing over a pulley near the eye end of the telescope. The entire attachment at the objective end is made of aluminium, and the total weight added to the telescope is 27 oz. As viewed with the slats partly turned, a bright star appears as a central stellar image with a line of spectral images extending on either side at right angles to the direction of the slats. Comparisons indicate that this novel appearance has no influence upon the probable error of a single chronographic signal.

TRIANGULATION OF STAR CLUSTERS.

BY E. E. BARNARD.

From the advantages given by the great scale of the forty-inch telescope, it was decided to measure the positions of a number of stars in some of the globular clusters, as a basis for the study of their motions in the future. For this purpose the clusters M 3, M 5, M 13, M 15, and M 92 were selected as representative.

In comparison with Scheiner's photographic measures of M 13 it was found that several of the stars had either diminished very greatly in brightness of late years, or that their light must come mostly from the blue end of the spectrum. The stars, 382 and 393 of his list, are striking examples. Both these stars are given by him as 12.7 magnitude. Visually, the first, which is his normal star, cannot be brighter than the 15th magnitude, while the second is at the limit of the great telescope and has been seen a few times only. Though it is possible that these stars may be variable, the observations do not seem to show it, except possibly in the case of No. 393.

VARIABLE STARS IN CLUSTERS.

BY E. E. BARNARD.

Some of the small variable stars discovered by Professor Bailey in M 13 have been regularly observed during the measures of that cluster. Besides the small variables there are three rather bright stars in this cluster which are also variable. Two of these were discovered eight or ten years ago by Mr. C. D. Packer, of London. These three stars vary slowly, requiring upwards of a month for their variations, and one of them has a much longer period. The three small stars, however, are very rapid in their changes, with nearly the same periods, averaging, as Professor Bailey has shown, about half a day. Variable No. 33, which rises from the 15th to about the 14th magnitude, and whose period is 12 hours 1 minute, has been specially observed at the request of Professor Bailey. The observations show that this object lies dormant for a large portion of its period as a faint star of the 15th magnitude. It suddenly begins to brighten, and in about fifteen minutes has doubled its light; it then slowly declines to a position of rest.

Several new variables were found in this cluster that are not marked on the Harvard photographs.

THE FIFTH SATELLITE OF JUPITER.

BY E. E. BARNARD.

The fifth satellite of Jupiter was observed with the forty-inch telescope, both in 1898 and 1899, and good measures obtained of it. From the elongation distances obtained at these observations a new value for the motion of the line of apsides of the orbit was determined. This was found to amount to 900° a year, or a complete revolution in 4.9 months. With this value of the motion of the perijove, all the elongation distances observed for the past seven years were accurately represented. A new determination was also made of the periodic time which is 11 h. 57 m. 22.647 s. As this period was derived from nearly five thousand revolutions it is probably very accurate.

THE ANNULAR NEBULA IN LYRA.

BY E. E. BARNARD.

A number of the planetary nebulae have been observed and measured. The position of the nucleus of the annular Nebula in Lyra (M 57) was carefully measured in 1898 and 1899. These, compared with Mr. Burnham's measures in 1891 with the thirty-six-inch telescope of the Lick Observatory, seem to show a sensible proper motion for the whole of about 0″.13 annually. This can be verified with certainty by measures four or five years hence.

The small stars near this nebula measured by Professor Hall at Washington in 1877, have been remeasured and the observations show that one of these stars (*f* of Hall's list) of the 15th magnitude seems to have considerable proper motion.

DIFFERENCE OF DECLINATION OF ATLAS AND PLEIONE.

BY E. E. BARNARD.

The summers and winters of Williams Bay subject the forty-inch to extreme ranges of temperature. Micrometer measures were made in all temperatures between + 80° F. and — 26° F. These observations showed that the focus of the great objective changed to the extent of about 0.7 inch—shortening with the cold weather. To test these changes, a great number of measures of the difference of declination of Atlas and Pleione of the Pleiades, had been made in

1897, 1898 and 1899. These measures besides showing considerable temperature changes, also show some peculiarities not satisfactorily accounted for and which do not show in similar measures of Electra and Caeleno, and which could be explained by a slight oscillation in the position of one of the stars. It is intended further to continue these measures.

ON THE MOTION OF HYPERION.

BY ORMOND STONE.

If, in the first approximation, the motion of the perisaturnium of Hyperion be assumed to be $4n' - 3n$, in which n and n' are the instantaneous mean motions in longitude of Titan and Hyperion, the perturbative function will contain an expression of the form

$$C_1(e_0 + e'[1 + \cos(4l' - 3l - \pi')]),$$

in which C_1 is a function of the mass of Titan and the mean distances from Saturn of Titan and Hyperion, e_0 is the quasi-eccentricity of the orbit of Hyperion introduced by the erroneous assumption in regard to the mean motion of the perisaturnium, e' and π' are the eccentricity and longitude of perisaturnium properly so-called, and l' and l are the longitudes in orbit of Hyperion and Titan, the motions of the two bodies being considered co-planar.

Integration, assuming the values of the coefficients given by Newcomb in his *Astronomical Papers,* Vol. III, and comparison with Eichelberger's value of the inequality in mean longitude detected by Hermann Struve, results in two solutions, giving rise to two sets of values for m, the mass of Titan, and e':

$$m = 1/5000, \qquad e' = 0.0224,$$
$$m = 1/4370, \qquad e' = 0.0195.$$

As neither of these values of m differs greatly from the more reliable values found hitherto, it is uncertain which of the solutions is the correct one, and we can only say, at present, that the true value of the eccentricity of the orbit of Hyperion probably does not differ greatly from 0.02.

THE VARIABLE VELOCITY OF POLARIS IN THE LINE OF SIGHT.

BY W. W. CAMPBELL.

Polaris furnishes an interesting case of variable velocity in the line of sight. Six spectrograms were obtained in 1896, as follows:

Gr. M. T. 1896,	September	8^d	$22^h.8$	—20.1 km.
	September	15	22 .8	—19.1
	September	23	21 .4	—18.9
	October	5	21 .0	—19.0
	November	11	19 .3	—20.1
	December	8	16 .7	—20.3
			Mean	—19.6

The agreement of these results, was satisfactory, and gave no evidence of variable velocity.

In order to test the current results of our work, another photograph of the spectrum of Polaris was obtained on August 8, 1899. This yielded a velocity of — 13.1 km., and led to the suspicion that we were dealing with a variable. Two additional plates were secured on August 9th and 14th, which yielded velocities of — 11.4 and — 9.0 km., respectively. Inasmuch as a range of four kilometers is not permissible in the case of such an excellent spectrum, the star was suspected to be a short period variable and further observations were obtained, as below:

Gr. M. T. 1899			Velocity	Measured by
August	9^d	0.8^h	—13.1	Campbell
	9	20.1	—11.4	Campbell
	14	22.8	— 9.0	Campbell
	16	0.1	—14.1	Campbell
	23	0.3	—10.9	Campbell
	24	0.8	—15.2	Campbell
	26	0.9	— 9.4	Campbell
	*		— 8.6	Wright
	27	0.3	—10.6	Campbell
	27	16.2	—14.0	Campbell
	28	0.8	—14.7	Campbell
	*		—14.3	Wright
	28	16.3	—13.7	Wright
	29	0.4	—12.1	Wright
	29	18.8	— 9.6	Wright
	30	0.0	— 8.9	Wright
	30	16.2	— 9.3	Wright

*Measures of the same plate by Mr. Wright.

On plotting these observations it became evident that Polaris is a spectroscopic binary, having a period a little less than four days

The 1899 observations have been collected and plotted on the assumption that the period is 3^d 23^h. The velocity, at present, seems to be included between — 8.6 and — 14.6 km., having an extreme range of only six kilometers. The velocity of the binary system seems to be about twelve kilometers.

The determinations of velocity made in 1896 lie entirely outside of the present range of values, and leave no doubt that the velocity of the binary system is changing under the influence of an additional disturbing force. I think it is certain, therefore, that Polaris is at least a triple system.

The 1896 observations were made at intervals differing but little from multiples of the period of the binary system, and therefore fell near the same point in the velocity curve. Assuming a period of 3^d 23^h ±, there is no difficulty in selecting the epoch of minimum so that these six observations will fall on the curve satisfying the 1899 observations. The residuals will be negligible if we assume the observations to fall near the lower part of the curve; and I have no doubt that future determinations of the orbit will definitely place them there. It will be seen that the velocities of the binary system in 1896 and in 1899 differ about six kilometers.

THE SPECTROSCOPIC BINARY CAPELLA.

BY W. W. CAMPBELL.

An examination of six spectrum plates of α Aurigae, obtained with the Mills' Spectrograph in 1896-7, leaves no doubt that this star is a spectroscopic binary. The spectrum is composite. The component whose spectrum is of the solar type furnished the following velocities with reference to the solar system:

1896,	August	31	+34 km.
	September	16	+54
	October	3	+49
	October	5	+44
	November	12	+ 4
1897,	February	24	+ 3

On the first photograph the spectrum is of essentially normal solar type; on the others it is unmistakably different. There appears to be a second component whose spectrum contains the $H\gamma$ line and the rather prominent iron lines. On the plates of September 16, October 3, and October 5, these lines are shifted toward the violet with reference to the solar type spectrum; and in the spectra of November 12 and February 24, they are shifted toward the red.

ON THE DETERMINATION OF THE CONSTANT OF NUTATION FROM HELIOMETER OBSERVATIONS OF EROS.

BY KURT LAVES.

The opposition of Eros at the end of next year will grant very valuable material for the determination of N, the constant of nutation. In No. 3156 of the *Astronomische Nachrichten,* I have pointed out that this constant could be well determined from heliometer observations of such small planets as come nearer to the earth than the astronomical unit. In the discussion of the heliometer observations of Victoria, made for the purpose of deriving a reliable value of the mean solar parallax, Dr. Gill has carried out this plan. He has found $N = 9''.2068 \pm 0''.0034$ (see *Annals of the Cape of Good Hope,* Vol. VI, part 6). This result agrees excellently with the value of N derived from direct observations. The reason for this agreement is due to Dr. Gill's new value derived for L, the constant of lunar equation. Indeed, in a former attempt to obtain N by this method, I had employed Leverrier's value $L = 6''.50$, and I was led to a value of $N = 9''.26$. The classical work of Dr. Gill has shown beyond doubt, that the correct value of L is much smaller; Dr. Gill gives for it $6''.414 \pm 0''.009$. With this value he has obtained the result mentioned above. The quantities on which the final determination of N depend are: the constant of luni-solar precession p^0, the mean solar parallax π^0, the constant of lunar equation L and the inclination of the moon's orbit to the ecliptic c. We find

$$dN = 0.45dL - 0.34d\pi^0 + 0.17dp^0 + 0.002dc.$$

It is thus evident that the small probable error of L in Dr. Gill's value has mainly reduced the formerly large probable error of N. We may regard the probable errors of L π^0, p^0, c are as follows:

$$\Delta L = \pm\ 0''.009; \qquad \Delta\pi^0 = \pm\ 0''.005;$$
$$\Delta p^0 = \pm\ 0\ .004; \qquad \Delta c = \pm\ 1\ .$$

ΔL and $\Delta\pi^0$ are the values obtained from the heliometer observations of Victoria. The smallest geocentric distance of this small planet was 0.82. The greatest geocentric displacement observable for the purpose of determining L was $15''$ (this displacement is due to the semi-monthly translatory motion of the earth's center about the center of gravity of the system earth-moon).

During the next opposition of Eros this planet will be at a mean geocentric distance of 0.34 for about eight weeks, the displacement witnessed will amount to about $37''$. From this it is evident that a systematic series of heliometer observations of this interesting object, will both give us a much more accurate value of π^0 and grant an excellent redetermination of *L*. It is found that the magnitude of Eros will vary between 8.8 and 9.7 during this time. The most favorable opposition possible for Eros will reduce the geocentric distance to 0.15. Assuming the mean distance for two weeks to be 0.20 we shall have an angle of nearly 64″ available for heliometric measurements.

INNER POTENTIAL FORCES IN ASTRONOMY.

BY KURT LAVES.

In No. 445 of the *Astronomical Journal* an investigation was published concerning the ten integrals of the problem of n bodies for forces involving the coordinates and their first and second differential quotients. The conclusion was reached that the new potential function W must be an arbitrary function of the mutual distances and relative velocities of the n bodies and must not contain the time explicitly, in order that the ten integrals should hold. In a communication to the Academy of Sciences of Leipzig on January 9, 1899, Professor A. Mayer, of Leipzig University, has recently taken up the same problem. His investigation deals with the problem in a more general way and has brought to light an oversight of mine in the above definition of W. Following this W should, in addition to the arguments mentioned above, contain the differential quotients of the mutual distances. It is my intention to give a detailed account of Professor Mayer's paper in one of the next issues of the *Astronomical Journal.*

THE ABERRATION CONSTANT FROM MERIDIAN ZENITH DISTANCES OF POLARIS.

BY A. HALL, JR.

A series of measurements was begun by the author with the meridian circle of the Detroit Observatory of meridian zenith distances of Polaris, with the idea of determining the aberration constant and the latitude variation.

Measures were made above and below the pole, direct and reflected, but the number of reflected observations has been rather small. A rough reduction of the observations made between May 1898, and July 1899, gives the following values for the aberration constant:

	Direct	Reflected
Upper Culmination	20″.60	20″.66
Lower Culmination	20 .58	20 .40

THE PHONOCHRONOGRAPH AND ITS ADVANTAGES IN CERTAIN ASTRONOMICAL OBSERVATIONS.

BY M. B. SNYDER.

In all kinds of astronomical observations, where phenomena, especially of an unpredicted character, rapidly succeed each other, it has invariably been found extremely difficult to make time records that can subsequently and with certainty be identified with the phenomena. Even with tried assistants as recorders, and with a prearranged code of chronographic signals there is usually a double failure; first, the proper records are not made by the assistants, and secondly, the time signals can not be satisfactorily identified.

The phonochronograph, as for brevity I designate a high grade phonograph also transformed into an efficient chronograph, seems fully to obviate the difficulties mentioned. The instrument records any vocal expression made by the observer along with a simultaneous sound automatically produced every second or two by the clock or chronometer. The record both for time, and for character of phenomena, is unbiased, absolutely identifiable, and can be read off without introducing any reaction time, excepting that originally entering.

The instrument consists of a phonograph whose cylinder rotates uniformly, and whose sliding carriage, which by turns bears both the recorder and the receiver, also has attached, near a second mouthpiece, a small electromagnet whose armature is attached to a light wooden hammer, which at each closure of the electrical circuit by the clock, strikes a small resonating box placed opposite the second mouthpiece. With properly selected resonating box, it is found that not only can the time signal always be read off by ear as distinct from the vocal record, but be visually distinguished as well. For the purpose of reading off the time record, so as not again to interpolate a reaction time, the sliding carriage also bears a microscope of moderate power, which is placed at an angle of about ninety degrees back of the recording diaphragm and enables one clearly to distinguish the clock from the vocal records. To enable the angular distance between the clock record and any given vocal record to be read off, a graduated circle, with stationary index, is attached to the end of the phonographic cylinder. The instrument is also provided with a rotameter, which rests on the surface of the cylinder and indicates the linear, instead of the angular, distance between records.

With present chronographic appliances it is feasable to construct a phonochronograph that will run for ten minutes, and it seems mechanically possible to treble this at least.

In observations of the meteors, where unexpected features occur, and particularly in solar eclipses, the phonochronograph seems to possess peculiar advantages. It is also suggested that the usual seconds-counting done by an assistant during totality can be done, without any special sacrifice or nervousness, by a phonographic cylinder previously prepared.

ACTINISM OF MOONLIGHT IN A TOTAL ECLIPSE.

BY G. W. HOUGH.

Near the middle of the total eclipse of the moon, on December 27, 1898, two negatives were made with the finder telescope, on a Seed 27 plate, with an exposure of five minutes each.

The resulting negatives gave good printing density.

Near the end of totality it clouded, but on the following night a number of negatives were made with the same telescope with reduced apertures.

It was found that an aperture of 0.16 inch, and an exposure of ten seconds gave a negative similar to that made during the eclipse.

From these experiments the actinism or photographic power of the eclipsed moon was found to be 1/17,000 that of the uneclipsed moon. The eclipsed moon was not equally luminous, and the photographic power might range between 1/17,000 and 1/30,000.

Young's *General Astronomy* gives the photographic power of the eclipsed moon of January 28, 1888, as determined by Professor Pickering, as 1/1,400,000 that of the uneclipsed moon.

I had intended to determine definitely, with my sensitometer, the total actinism of the eclipsed moon, but the exposures which were made for me by a student in astronomy were all too short to be of use.

In 1892 I published a table giving the relative sensitiveness of a considerable number of commercial dry plates for sunlight, candle light, and through red glass. For the rapid plates it was found that the color-sensitized plates were twice as sensitive in the yellow and eight times as sensitive in the red light as the ordinary plates.

As the light of the eclipsed moon is always colored, it is obvious that its actinism or photographic power will depend on the kind of plate employed; and possibly on its manipulation previous to development, owing to the effect of preliminary or supplementary exposure.

CARBON IN THE CHROMOSPHERE.

BY GEORGE E. HALE.

The level at which carbon vapor exists in the atmosphere of the sun was definitely ascertained in 1897 with the forty-inch Yerkes telescope, when the green carbon (or hydro-carbon) fluting was found in the spectrum of the chromosphere. The layer of carbon vapor to which the fluting is due is not more than a second of arc in thickness, and lies in immediate contact with the photosphere. For this reason it can be observed only with the most powerful telescopes, used under the most perfect atmospheric conditions. The fluting has been repeatedly seen at the Yerkes Observatory during the past summer, and its individual lines identified with the dark lines in the solar spectrum ascribed by Rowland to carbon. On August 17th the yellow carbon fluting, which is more difficult than the green fluting, was also found. These observations reveal an interesting similarity of the sun to red stars of Secchi's fourth type, in which a dense absorbing atmosphere of carbon (which is far more conspicuous than in the sun) has recently been found with the forty-inch telescope to be surmounted by an atmosphere giving a spectrum of bright lines.

SOME NEW FORMS OF SPECTROHELIOGRAPHS.

BY GEORGE E. HALE.

Of the various forms of spectroheliographs described in my previous papers, the simplest and best is undoubtedly that in which the instrument is moved as a whole at right angles to the axis of the telescope, the solar image and the photographic plate remaining stationary. It is not always possible, however, to employ a spectroheliograph of this form. With the forty-inch telescope, for example, the motion of the very heavy spectroheliograph required could not be accomplished without jarring the instrument. For this reason it has been decided to cause the solar image to move across the first slit by means of the slow motion declination motor. The first and second slits are fixed with reference to each other, and the photographic plate is moved across the second slit by means of a screw driven by the same motor, which is mounted on the tube of the forty-inch telescope. A wide range of exposures can be secured by means of a system of change gears. This spectroheliograph, which has an aperture of 6¼ inches, is now ready for trial.

Two other forms of spectroheliographs may occasionally prove useful. The solar image is moved across the first slit in the one case by means of a photographic doublet, of large field, mounted between the slit and the principal focal plane of the image lens, and in the second case by means of a right angle prism, placed immediately in front of the first slit, with hypotenuse face parallel to the optical axis of the collimator. A suitable combination of mirrors may be used instead of the prism. The doublet and prism are connected with a carriage bearing the photographic plate across the second slit, and are moved in a direction at right angles to the optical axis of the collimator. Either device, used in conjunction with a heliostat, affords an easy means of transforming a large fixed laboratory spectroscope, of almost any type, into a spectroheliograph.

COMPARISON OF STELLAR SPECTRA OF THE THIRD AND FOURTH TYPES.

BY GEORGE E. HALE.

As previous observations of the faint red stars of Secchi's fourth type have shown none of the lines in their spectra it has been impossible to effect any satisfactory comparison of these stars with the red stars of the third type. So far as their characteristic features go, the spectra are quite dissimilar, the pronounced carbon absorption bands of the fourth type having no counterpart in the banded spectra of the third type stars. The photographs of these spectra recently obtained with the forty-inch telescope by Mr. Ellerman and the writer, contain hundreds of lines, and render comparisons possible. From these plates it has been found that in certain limited regions third and fourth type spectra are almost identical. It is therefore, probable that the stars of these two great classes are closely related to each other and to stars like the sun. The study of fourth type stars is being continued at the Yerkes Observatory.

THE REVISED HARVARD PHOTOMETRY.

BY E. C. PICKERING.

In the *Harvard Photometry*, all stars were inserted having the magnitude 6.0 or brighter in any of the principal star catalogues then published. Accordingly, as was expected, many fainter stars were included, since a star really faint, but estimated bright by mistake in any of these catalogues, would be entered and measured. It appears that from this cause, and from the varying scale in different catalogues, more than six hundred stars are included, which are fainter than the magnitude 6.2 on the photometric scale. (See *H. C. Annals*, Vol. XIV, p. 479). Numerous measures of the brighter stars have been made in recent years, with the large meridian photometer which has replaced the instrument first used. They include 823 stars measured in connection with fainter stars in Vol. XXIV, Table I, and 1179 stars in Vol. XXIV, Table IV. Measures of all the bright stars south of declination — 30°, are published in Vol. XXXIV.

The stars of the *Harvard Photometry* were again observed in 1892-1894, and the results are now being published in Vol. XLIV. A large number of them were also measured in 1895-1898, when determining the brightness of stars of the magnitude 7.5 and brighter north of declination — 40°. Finally, the stars south of declination — 30° are now being remeasured in Arequipa, by Professor Bailey. In a recent letter, he states that sixteen series were obtained on sixteen successive nights, and that 11,448 settings were made during the month of May, 1899. It is hoped that this work will be completed during the present year.

It, therefore, appears that seven photometric catalogues of these stars have been prepared. In Vol. XXIV, Table I, some stars were observed on only two nights, but in all other catalogues the minimum number of nights is three, and for many of the stars, especially for those that are bright, the number is much greater. When the observations were not accordant the minimum number of nights was five in Vol. XXIV, Part I, and seven or more in the other catalogues. The number of photometric settings on each star each night was generally four, but was occasionally eight or more in the later work. The total number of photometric settings, including those of the fainter stars, will slightly exceed one million. It will be seen, therefore, that a large number of measures of all the bright stars have been made according to the same plan, but with different instruments and by different observers. Each star should appear in at least two of the seven catalogues, and generaly in three or more.

It is, therefore, proposed to issue a catalogue of all the stars from the north to the south pole of the magnitude 6.0 or brighter according to the meridian photometer, which will show the brightness as given in each of the seven catalogues. This work, which will be called the *Revised Harvard Photometry*, will also contain other facts, such as the approximate right ascension and declination for 1900; the designation according to Bayer, Flamsteed, the *Durchmusterung*, the *Argentine General Catalogue*, the *Harvard Photometry* and the *Southern Harvard Photometry;* the magnitude according to Herschel, the *Durchmusterung*, the *Argentine General Catalogue*, the

Uranometria Oxoniensis, and the *Potsdam Catalogues*; the class of spectrum, and, if possible, the photographic magnitude. This would also furnish a quantitative measure of the color.

As it is believed that this catalogue will be found convenient for general reference, the value would be greatly increased if the precise position, the precession, the secular variation, and the proper motion were added. This does not seem advisable, however, since owing to the uncertainties of proper motion, and systematic errors in various catalogues, the labor involved in this work would be very great, and probably many astronomers would be dissatisfied with the results, however obtained. A simple plan would be, for the northern stars, to take the positions for 1875 given in the catalogues of the *Astronomische Gesellschaft,* and for the southern stars those given in the *Argentine General Catalogue.* Residuals for a few other catalogues could be given and thus permit other places to be used if desired. These positions would be sufficiently accurate for stars of the eighth and ninth magnitudes, but they would be far from representing the accuracy with which the places of the brighter stars are known. Any suggestions and criticism relating to the above plan will be gratefully accepted, as it is not yet too late to make use of them.

SOME RESEARCHES IN STELLAR COLOR.

BY G. C. COMSTOCK.

By placing a coarse grating in front of the objective of a telescope the image of a star is broken up into a series of a spectra symmetrically placed on opposite sides of a central image, and, as is well known, the distance of the several spectra from the central image depends upon the grating interval and the wave-length of the light in question. When the grating interval is large, *e. g.,* 10 mm. to 50 mm., the first order spectra of stars are almost indistinguishable from stellar points, and if their angular separation is measured with the filar micrometer an excellent determination of the mean wave-length of the light in question is easily obtained. Observations of this kind are in progress with the 40 cm. equatorial telescope of the Washburn Observatory, special attention being given to colored stars, and to the planet Mars for the purpose of determining any possible effect of the stellar and planetary color upon observations for the determination of the solar parallax. While definite results are not yet obtainable, it may be stated in general that the mean refrangibility of the light of Mars is markedly less than that of any of red stars yet examined.

Attention has also been given to the color of Jupiter's satellites on account of the application of interference methods to the determination of their diameters made by Michelson and Hamy. Both of these investigators appear to have assumed too small values of the mean wave-length, that of Hamy requiring to be reduced about twelve per cent.

REFRACTION OF RED STARS.

BY F. L. CHASE.

Gill in 1877 and Newcomb in 1895 have spoken of the importance of the effect that a difference in the refraction of Mars and minor planets from that of the comparison stars might have on the apparent parallaxes of the planets. Although feeling that in the case of Victoria and Sappho this color effect was inappreciable, as stated in his recent work on the solar parallax, Dr. Gill requested the several observatories engaged in solar parallax work to make a short series of heliometer observations on several highly colored stars. Not having time to carry out the program suggested by Dr. Gill, the author selected five other suitable stars and carried out the work as follows:

The plan was to observe the distances between the red stars, one preceding in right ascension and the other following it, and as nearly as possible on the same parallel of declination with it, first at a rather large hour angle when east of the meridian and again in the morning hours when west. Now it is evident that if the red star is lifted less by refraction than a comparison star which precedes it in right ascension, the distance between them on the east side of the meridian will be greater than it would be if both stars were white and less on the other, and *vice versa* if the comparison star follows it. By taking two comparison stars as described above we are able to eliminate any change in the scale value, any variation in the atmospheric refraction, and the difference of the two measured distances would evidently give double the effect we are considering.

Now the refraction of a star of average color may be represented by

$$R = \beta \tan z.$$

The refraction of a star with light of a different refrangibility would then be

$$R = (\beta + d\beta) \tan z.$$

It will therefore be easily seen that the refraction correction to the observed distance between two stars of different refrangibility should receive the additional correction

$$- d\beta \tan z \cos(p - q),$$

z, p and q having their usual significations of zenith distance, position angle, and parallactic angle respectively.

To each measured distance it would then be simply necessary to add the term

$$-\, d\beta \tan z \cos(p - q),$$

and to find the value of $d\beta$.

Now for finding the value of $d\beta$ the observations of each of the five red stars which were to be observed four times on each side of the meridian, would furnish eight equations of condition of the form

$$x + a\, d\beta = n,$$

where x is the necessary correction to the assumed value of the difference between the distances from the two comparison stars; a is the value of $\tan z \cos (p - q)$, and n is the observed difference of the two distances minus the assumed difference.

Combining the normals derived from these equations of condition for the observations of both last year and this, and solving, I find the following values for $d\beta$:

Star	Redness	$d\beta$	Weight
R_1	6.0	$+0''.020 \pm 0''.015$	63.6
R_2	7.1	$-0\ .008 \pm 0\ .014$	16.0*
R_3	7.0	$-0\ .015 \pm 0\ .020$	64.4
R_4	8.7	$-0\ .046 \pm 0\ .018$	45.2
R_5	7.8	$+0\ .008 \pm 0\ .024$	55.7

Average probable error of one observation $= \pm 0''.151$.
*Not observed in 1899.

A separate investigation was made along with that of star R_5, which was specially selected because it had a close neighboring white star. The distances of the white star from the same comparison stars were measured on the same nights and the observations were made symmetically with respect to those of the red stars, so that the conditions were absolutely the same for the two stars.

Similar equations for this white star gave

$$d\beta = +\, 0''.044 \pm 0''.022, \text{ Weight } 55.6,$$

as compared with $+\, 0''.008 \pm 0''.024$ for R_5.

The small values above found for $d\beta$ (in the mean for five red stars we find $d\beta = -\, 0''.006 \pm 0''.010$), and more especially the fact that two contiguous stars, one white and the other red, give no appreciably different results, afford rather forcible evidence that to my eye, at least, difference of color in the stars does not affect heliometer observations of distance.

THE RING NEBULA IN LYRA.

BY J. E. KEELER.

In order to test the capabilities of the Crossley three-foot reflector of the Lick Observatory, a number of photographs were made of well-known celestial objects. As the focal length of a camera should be from thirty to sixty times its aperture in order that the photographic and optical resolving power may be equal, it is doubtful if this nebula has ever been photographed with an entirely suitable instrument. As it is a small object and photographically bright, it could be advantageously photographed with a reflector of unusually long focus. The lenses of refractors absorb the actinic rays to such an extent that for such instruments exposures of even twenty hours have been given to this nebula. With the Crossley reflector, under the finest conditions, on July 14th of this year, an exposure of thirty seconds produced an image which was barely visible; one minute a faint image; two minutes a distinct image; and ten minutes gave the best general picture of the nebula. With one and two hours the plate was much overexposed. The focal length of this telescope is 17½ feet but if it were four times greater a far better photograph could doubtless be obtained, the necessary exposure then being about three hours.

The ratio of aperture to focal length could, however, be reduced by cutting down the aperture, thus diminishing the aberration and atmospheric disturbances. But for an object like this nebula the aberration is insensible, the star images being excellent at half an inch from the axis; moreover the photographs were taken on nearly perfect nights when the definition would not have been improved by reducing the aperture.

These photographs of the ring nebula show features described by observers with powerful visual and photographic telescopes, and others which appear to be new. The outline of the nebula is oval rather than elliptical, with faint structureless fringes of nebulosity projecting on both sides of the oval. The ring has quite a complicated structure, as if made up of several narrower bright rings, interlacing somewhat irregularly, the intervening space being filled with fainter nebulosity.

A comparison was given of the dimensions of the nebula as measured by Barnard with the Lick refractor, and as determined by Stratonoff on photographs obtained in ten hours exposure with a refractor of 33 cm. aperture, and as measured on a Crossley plate with ten minutes exposure. The author's measures give a somewhat greater size than the visual measures, and also average slightly more than on the Russian photograph.

Lord Rosse's drawing, published in the *Philosophical Transactions* for 1844, showing the interior space of the nebula to be crossed by a series of dark and bright bands, and hitherto generally deemed fanciful, is now confirmed, it is believed, for the first time.

The actinic power of the central star, noted by many observers, is also confirmed by these plates, being faintly visible on the plate exposed for thirty seconds. It is suggested that the photographic strength of this and other central stars may be due to bright lines, probably of hydrogen, in the upper spectrum; and the author does not anticipate difficulties in photographing their spectra. On all the photographs the central star is as clearly defined as are other stars outside the nebula; there is no evidence of blending into the nebulous background. This is also the appearance of the star as seen with the thirty-six-inch refractor. (Published in the *Astrophysical Journal,* Vol. X, pp. 193-201).

THE WAVE-LENGTH OF THE GREEN CORONAL LINE.

BY W. W. CAMPBELL.

One of the problems undertaken by the expedition sent from the Lick Observatory to observe the Indian eclipse of January 22, 1898, was the determination of the rotation of the corona from the displacement of the green coronal line. A powerful train of prisms loaned by Professor Young furnished the necessary high dispersion. A successful plate was obtained during the eclipse, and while measuring this in January, 1899, I learned that Lockyer had assigned a new wave-length to the green coronal line. On reducing my measures, with the aid of Hartmann's formula, I obtained a result in substantial agreement with his. The wave-length is

For East side, $\lambda = 5303.21$
For West side, $\lambda = 5303.32$

Mean, $\lambda = 5303.26$,

which should not be in error by more than ± 0.15 tenth meters. The difference in the determination for the two sides corresponds to a relative velocity of 6.2 km. in the line of sight, or a rotational velocity of 3.1 km. per second. However, I regard this result as subject to a possible error of at least ± 2 km. per second, partly on account of unavoidable errors of observation, but principally on account of the ill-defined and unsymmetrical character of the bright line.

The continuous spectrum of the inner corona was recorded out to a distance of $2'.5$ on the east side and $1'.5$ on the west side. While the dark lines in the recorded comparison spectra are sharp and strong, there is not the slightest trace of dark lines in the recorded continuous spectrum of the corona. This radiation seems to be of coronal origin, and is not due to reflected photospheric radiations.

In explanation of the error in the accepted value of the wave-length (λ 5317) of the green coronal line which has prevailed for many years, it is suggested that the true coronal line would be difficult to observe so long as the chromospheric spectrum was visible. Hence the observers, setting on the strongest chromospheric line in this region at λ 5317, which is very conspicuous just before and at the instant of totality, assumed it to be identical with the true coronal line, and located it at 14.74 K. Later, when this line had disappeared, rather suddenly, and the background had become dark enough to allow the line at λ 5303 to be seen, the observers were interested in the extent and other properties of the line and no further micrometer settings were made for fixing its wave-length. (Published in the *Astrophysical Journal,* Vol. X, pp. 186-192).

NOTES ON THE REDUCTION OF STELLAR SPECTRA.

BY EDWIN B. FROST.

The advantage was pointed out of using Hartmann's interpolation formula for the prismatic spectrum in the reduction of spectrograms taken either for the determination of wave-lengths or velocity in the line of sight. An outline was given of the procedure adopted in the latter work with the forty-inch refractor. Each plate is reduced by itself, independently of any solar or other plate, such as many observers have used as auxiliary in the process of reduction. The comparison spectrum from a spark between metallic electrodes, impressed upon each plate, furnishes all the data necessary for the reduction It is hoped that errors due to effects of temperature on the dispersion of prisms and focus of lenses are thereby reduced, and that systematic errors are also diminished.

Attention was called to the favorable results obtained from the use of titanium as a source of the comparison spectrum. The lines are numerous and well distributed throughout the upper spectrum. The metal stands third in Rowland's arrangement according to number of lines in the solar spectrum. The spark passes with great readiness between electrodes of metallic titanium, and the air lines, which are annoying in case of the spark spectrum of iron, are not produced. Sharp titanium lines are found to fall at points in the spectrum close to the positions of the principal lines of stellar spectra of Type I*b*, and thus facilitate the reduction of such spectra.

CORRECTIONS TO DETERMINATIONS OF ABSOLUTE WAVE-LENGTHS.

BY EDWIN B. FROST.

The effect upon absolute wave-length of lines in the solar spectrum of the eccentricity of the earth's orbit seems to have been hitherto neglected, presumably because the observers deemed it insignificant. The largest values, however, of the motion of the earth toward and from the sun, due to this cause, amount to 0.50 kilometer per second, in April and October; and if velocities of stars in the line of sight were determined directly from absolute wave-lengths, instead of relative wave-lengths, uncertainties of one-half of a kilometer would at once arise, in measurements now given to the tenth of a kilometer. Expressed in wave-lengths that velocity would produce a displacement of 0.011 tenth-meters at C; or 0.008 at F.

The diurnal correction to velocities in the line of sight, due to the earth's rotation, also seems to have been omitted in reducing measures of absolute wave-length. This might have an effect up to 0.006 tenth-meter at C or 0.005 at F.

The need of even a higher degree of accuracy than that yet obtained in relative wave-lengths was urged, as an error of 0.01 tenth-meter in the relative wave-length of either a stellar or comparison line (not coincident) whose separation is measured, produces an error of 0.7 kilometers per second in the velocity of the star as deduced from that line. (Published in the *Astrophysical Journal,* Vol. X, p. 283).

SUGGESTIONS FOR THE DETERMINATION OF STELLAR PARALLAX BY PHOTOGRAPHY.

BY FRANK SCHLESINGER.

As the star to be examined for parallax will usually exceed each of the comparison stars in brightness by six or seven magnitudes, the first problem is to reduce in some way most of the light of the brighter stars, in order to escape various errors which would arise in the measurement of star disks very unequal in size and appearance. It is suggested that the portion of the photographic film upon which the light of the principal star will fall be previously treated with some suitable dye, thus greatly reducing its photographic action.

To avoid a second source of error, distortion of the film after exposure, a modification of the method employed by Wilsing is suggested. Let two pictures be taken close to each other on the same plate at the first date; let the plate then be stored undeveloped in the dark room; after six months make two more exposures of the same star and comparison stars on the plate at a little distance from the previous impressions; this plate can then be developed and measured, without fear of any ill effects from distortion of the film. The first pair of exposures on a new plate may then be begun and this stored for six months; and so on until a sufficiently long chain of plates is secured to give good values both for the parallax and for the relative proper motions with respect to comparison stars.

It is proposed that errors of optical distortion caused by peculiarities of the object glass be eliminated from the parallax by rotating the lens in its own plane through 180° each time that the telescope is reversed. In this way the objective will present the same position relative to a stellar configuration, whether in the east or west, and optical distortion, if any, will shift all images of the same star alike.

According to the author's estimate, a single observer working fifteen or eighteen hours a week at the telescope and employing the rest of his time in measuring and reducing, could give us in three or four years the parallaxes of two hundred stars with an accuracy hitherto attained for only a score. (Published in the *Astrophysical Journal,* Vol. X, p. 242).

PERIODS OF THE VARIABLE STARS IN THE CLUSTER MESSIER 5.

BY S. I. BAILEY.

This cluster contains about nine hundred stars on the photographs made with the thirteen-inch Boyden refractor, of which about eighty-five, or one in eleven, are variable. The periods of about forty stars have been determined from measures made of 63 of these variables on nearly one hundred plates by the author and Miss E. F. Leland. The period and light curve of one of the stars in this cluster were determined by Professor E. C. Pickering in 1896, and the periods of three others by visual observations with the Yerkes refractor. A tabular statement was given of the periods, maximum and minimum brightness and range, and distances from the center of the cluster. Drawings were exhibited of the light-curves of the first eight variables in the group. The table disclosed a striking similarity among all these variables, not only in regard to length of period, but in magnitude and range of variation. Excepting No. 9, which has the exceptional period of $16^h\ 47^m$, the longest period among the forty stars is $14^h\ 59^m$, and the shortest $10^h\ 48^m$. The average period is $12^h\ 37^m$, so that the greatest deviation in period from the mean is $2^h\ 21^m$. At maximum these variables range between 13.4 and 13.9 magnitudes, and at minimum between 14.5 and 14.9 magnitudes. The uniformity of period, magnitude, and light curve among so many variables in the same cluster points unmistakably to a common origin and cause of variability. No such uniformity is found in the periods and light-curves of over one hundred variables determined by the author in the great cluster ω Centauri.

A few of the variables in M 5 have been studied with special care for the exact determination of the form of the light-curve, and diagrams were shown of two of these, which represent what may be called the 'Cluster Type' of variables. The decrease in brightness is rapid, but not nearly so rapid as the increase. The duration of maximum phase is exceedingly brief, if any; the minimum brightness appears to be quite constant for several hours. The whole period may be divided as follows:

Duration of maximum phase	0 per cent.
Duration of minimum phase	40 per cent.
Duration of decreasing phase	50 per cent.
Duration of increasing phase	10 per cent.

(Published in *Astrophysical Journal,* Vol. X, pp. 255-260).

NOTE ON THE RELATION BETWEEN THE VISUAL AND PHOTOGRAPHIC LIGHT-CURVES OF VARIABLE STARS OF SHORT PERIOD.

BY S. I. BAILEY.

With a visual telescope of sufficient power a series of frequent observations of a variable star will give the true form of its light-curve, since each observation consumes so little time that it is not affected by the star's variability. The same would be true of photographic observations if the time of exposure could be made so short as to bear an inappreciable ratio to any change of phase. This applies to most long-period variables. Certain short-period variables, however, notably those belonging to dense clusters, are so faint and go through their changes, especially the increase in light, so rapidly, that the necessary exposure bears a very large ratio to the duration of any phase and important modifications in the form of the light-curve follow.

When the light of a star is changing at a uniform rate and in the same direction, the measured magnitude will approximately represent the actual photographic magnitude at the middle time of exposure, but it is obvious that sharp changes in the light of a variable will not be well registered on photographs of relatively long exposure. A diagram was shown of an assumed light-curve, where the exposure required was one-half of the period of the star's entire variation, and the rise and fall of the brightness were equally rapid. Here no photograph of the required exposure would record a complete minimum, but would fall above it, and similarly would fall below the true maximum. Thus the tendency of the photographs is to smooth down the curve, reducing the star's apparent range of variation.

Where the increase and decrease of light are of different rapidity, as is usually the case, the result will be different. A diagram was shown of a slightly modified light-curve of variable No. 7 of cluster M 5. In order to represent the variable at a complete minimum the exposure must close before the beginning of the maximum phase. The photograph, the middle of whose exposure is at the beginning of maximum, will have the first half of its exposure at minimum and will record the variable as of less than maximum brightness, and the maximum possible on such plates will be recorded on the exposure commencing at the beginning of maximum. With the usual exposure of one hour for this cluster, the photograph beginning an hour before maximum would record the minimum photographic magnitude. This retardation will depend upon the light-curve and the exposure time. In general the difference in time between the photographed and the actual maximum or minimum varies, with zero as a limit, as the exposure is reduced. Evidently a large telescope and very sensitive plates are desirable.

Probably the shortest period yet found is that of No. 91 in ω Centauri, $6^h\ 11^m$; as it is not improbable that much shorter periods may be discovered, it is clear that the relation of the exposure to the period becomes very important. (Published in the *Astrophysical Journal*, Vol. X, p. 261).

Neither the original papers nor abstracts have been obtained of the following:

ON THE SEMI-DIAMETERS OF THE SUN AND MOON

BY WILLIAM HARKNESS.

PROBLEMS IN MODERN CELESTIAL MECHANICS TREATED BY THE USE OF POWER SERIES.

BY F. R. MOULTON.

LAPLACE'S RING NEBULAR HYPOTHESIS.

BY F. R. MOULTON.

SECOND MEETING

The second annual meeting of the Society was held on Tuesday, Wednesday and Thursday, June 26-28, 1900, at Columbia University, in the City of New York, in connection with the forty-ninth annual meeting of the American Association for the Advancement of Science.

The number of papers actually read before the Society at this meeting was approximately the same as at previous conferences, but many of these were technically presented to Section A of the American Association, and were read at the joint sessions of that Section with the Astronomical Society. Only those papers which were formally presented to the Society and of which abstracts have been submitted by the authors are summarized below.

A new feature of the Society's program was the discussion of the observations made at the total solar eclipse of May 28, 1900, accompanied by the presentation of numerous photographs of the eclipse, and the discussion of the program for observing the planet Eros during its close approach to the earth in the autumn and winter of 1900-1901. A summary of these discussions follows the abstracts of papers presented.

The election took place on the last day of the meeting, resulting in the following list of officers for the year 1900-1901:

President	Simon Newcomb
First Vice-President	Charles A. Young
Second Vice-President	George E. Hale
Secretary	George C. Comstock
Treasurer	C. L. Doolittle
Councilors	Edward C. Pickering James E. Keeler Ormond Stone Stimson J. Brown

RESOLUTIONS ADOPTED

The following resolutions were adopted by the Council:

Resolved, That the Astronomical and Astrophysical Society of America extends to the Chief of the U. S. Weather Bureau its hearty thanks for his courtesy in transmitting daily weather bulletins to those astronomers who observed within the United States the total solar eclipse of May 28, 1900.

Resolved, That the Astronomical and Astrophysical Society of America extends to the Western Union Telegraph Company its hearty thanks for the courtesies extended by it to those astronomers who observed within the region covered by its lines the total solar eclipse of May 28, 1900.

ABSTRACTS OF PAPERS

THE RATE OF INCREASE IN BRIGHTNESS OF THREE VARIABLE STARS IN THE CLUSTER MESSIER 3.

BY S. I. BAILEY.

The proportion of stars found to be variable in the cluster Messier 3, N. G. C. 5272, is greater than in any other object of the same class. This object is so low, however, at Arequipa, and the stars are so faint that satisfactory photographs of it, with the thirteen-inch Boyden refractor, cannot be obtained with exposures of less than ninety minutes. The rate of increase of the light of many of these stars is extremely rapid and in order to determine this change with the highest precision, photographs of very short exposure are necessary. At the request of the Director of the Harvard Obesrvatory a series of most admirable photographs of this cluster were taken with the three-foot Crossley reflector by Professor James E. Keeler, Director of the Lick Observatory. These photographs were taken on May 20 and 21, 1900. The first plate had an exposure of sixty minutes, but all the others twenty-four in number had exposure of only ten minutes, while showing the variables at minimum magnitude. The shortness of these exposures, combined with the high quality of the plates, make the results obtained very satisfactory.

Three variable stars have already been measured on these plates. They are Nos. 11, 96 and 119. The series of plates extended from

$17^h\ 42^m\ 46^s$ to $20^h\ 24^m\ 11^s$ on the night of May 20th, and from $17^h\ 2^m\ 38^s$ to $20^h\ 53^m\ 27^s$, May 21st, G. M. T. These periods of time covered the entire interval from minimum to maximum, for each of the above stars on at least one night. The same stars were also measured and forty-nine photographs made at Arequipa during the years 1895-1899. From a study of all these measures I find the periods to be: No. 11, $12^h\ 12^m\ 25^s$; No. 96, $12^h\ 0^m\ 15^s$; No. 119, $12^h\ 24^m\ 31^s$. For the following discussion of the rate of increase, however, only plates made by Professor Keeler, on the night of May 21st, and having exposures of ten minutes were used.

The measures of the brightness of the variables were made by Argelander's method, using a sequence of comparison stars whose magnitudes have not yet been determined. The results are, therefore, given in grades. The value of one of these grades is somewhat uncertain, but is not far from a tenth of a magnitude, since in a previous work the value of my grade has been 0.085 of a magnitude. The observations were then plotted, using vertical distances to represent magnitudes and horizontal distances to represent time, and a smooth curve was drawn through them. The time scale employed in this drawing was very open, in order to read with greater accuracy the ordinates of the curve corresponding to intervals of five minutes. The results of the measures are very accordant. Of all the measures on the Lick plates of ten minutes' exposure the average deviation from the curve is less than half a grade.

From these curves it appears that the total increase of light, amounting to 17.5 grades in the case of variable No. 11, takes place within seventy minutes; in the case of No. 96, an increase of 16.7 grades occurs within sixty minutes; and No. 119, 17.0 grades, within seventy-five minutes. The maximum increase during any interval of five minutes, is, in the case of No. 11, 1.9 grades; No. 96, 2.5 grades; No. 119, 1.5 grades. During thirty minutes No. 11 increases in magnitude 10.9 grades, or at the rate of 21.8 grades per hour; No. 96, 12.8 grades, or at the rate of 25.6 grades per hour; No. 119, 8.6 grades, or at the rate of 17.2 grades per hour. The greatest rapidity is met in the case of No. 96, where for five minutes the increase is at the rate of thirty grades, or about 2.5 magnitudes per hour, and during thirty minutes has a rate of 25. 6 grades, or more than two magnitudes per hour. This rate of change appears to be more rapid than that of any other star known.

The Agol variable U Cephei, which perhaps undergoes the most rapid change of any star not found in clusters, changes at the rate of about one and a half magnitudes per hour, during the half hour when its increase and decrease are most rapid. The total times of increase of the three stars, 70, 60 and 75 minutes, are 9, 8 and 10 per cent. respectively, of their whole periods. Near the beginning and end of increase, however, the rate of change seems to be relatively much slower. If we allow one and a-half grades for each of these slow changes, making three grades in all, we find that the remaining increase, amounting to more than four-fifths of the whole change in light, takes place for the three stars in 42, 34 and 54 minutes, respectively. That is, in about 6, 5 and 8 per cent. of their respective full periods.

In the case of No. 96 this increase is about ten times as rapid as the corresponding decrease. In general it may be stated that the length of periods and form of light-curves are similar to many of those in the clusters Messier 5 and ω Centauri. (See *Astrophysical Journal*, Vol. X, p. 255). It will be noted that the periods of these three stars are about one-half a day. Several other variables in this cluster appear to have approximately the same period.

THE SERIES OF PARALLAXES OF LARGE PROPER MOTION STARS MADE WITH THE YALE HELIOMETER.

BY F. L. CHASE.

A large proper motion is, as is well known, the strongest indication of a star's nearness. Some years ago it seemed to us at the Yale Observatory that it would be a promising task to make a rather sweeping survey of all the fainter northern stars having a large proper motion to single out those which show a measurable parallax. Our list was based upon Porter's Catalogue of Proper Motion Stars, and it was our aim to take up all the stars therein contained, which showed an annual motion as great as 0″.5 excepting such as had already been observed for parallax.

It was hoped that among so large a number, nearly a hundred, some very near neighbors should be found, but in case that the results should prove wholly negative it would afford some satisfaction to know that there are probably no more stars in the northern skies within a certain distance of us.

This research was begun in the summer of 1892, soon after Porter's Catalogue appeared, and has been the problem of chief attention on my part since that time. There were eighty-six stars in my list and thirteen in Dr. Elkin's of which I have completed the observations of eighty-four and Dr. Elkin's eight. The original plan was to observe each star on three different nights near each of the two epochs of maximum parallactic effect. For each star when possible two suitable comparison stars were chosen on opposite sides of the principal star and as nearly as possible at the same angular distance from it. The observations were made in the customary symmetrical order S 1, S 2, S 2, S 1; S 1 denoting the angular distance from one comparison star and S 2 the distance from the other.

At first it was intended to use the known proper motions in the reductions, and it was thought that three observations at each of the two epochs would be sufficient to show any parallax as great as 0″.2. and any such cases were to be further investigated. Later it seemed to us to be desirable to eliminate the effort of proper motion independently, which can be quite thoroughly accomplished by repeating the observations through two more epochs in the reverse order, and at the same time this enlarged number of observations should furnish a pretty fair approximation to the true value of the parallax.

The plan thus modified would give us twelve complete observations for each star, which number was secured in nearly every case. Each of these complete observations furnishes an equation of condition of the form:

$$x + by + cz = n$$

where x represents the required correction to the assumed scale value, y the parallax, z the correction to the assumed annual proper motion, b the parallax factor depending upon the positions of the stars and that of the earth at the time $c = t - 1895.0$, (1895.0 being about the middle of the period covered by the observations), and n equals the difference S 1 — S 2 minus an assumed value for this difference.

The normals from these equations of condition have all been formed and a preliminary solution has only just been finished. As to the results I may say that a little disappointment was felt that no very large parallaxes were found. However there were two stars viz: 54 Piscium and Weisse 17^{h} 322, which show a parallax of nearly 0″.25 and which, therefore, if the results are confirmed by further observation, will place them among the first ten or twelve nearest stars so far as at present known. I have selected for each of these stars two new pairs of comparison stars and have nearly completed a more extended series of observations of them. The final parallax will in each case depend upon fifty-six complete observations instead of twelve as at present.

A preliminary classification, according to the magnitude of the parallax found, may be of some interest and is given in the following table.

Parallax.			No. Stars.
0″.20	to	0″.25	2
0 .15	"	0 .20	6
0 .10	"	0 .15	11
0 .05	"	0 .10	24
0 .00	"	0 .05	34
—0 .05	"	0 .00	8
—0 .10	"	—0 .05	5
—0 .15	"	—0 .10	2

The probable error of a single observation comes out to be on the average about ± 0″.170. Taking the average weight of the parallax to be 30.0 the average probable error of the values of the parallax found would be ± 0″.031. In this no account has been taken of the systematic error of the observer which has not yet been discussed for this problem. It should also be borne in mind that the parallax here found is only the relative parallax to which should be added that of the comparison stars employed.

It is our purpose further to classify the results. 1st, according to the magnitude of the stars, and 2nd, according to the amount of the proper motion which may perhaps lead to interesting conclusions. The results here given may perhaps be slightly modified in the fuller discussion, but in their present form they may serve to give some idea of a piece of work, which we hope will contribute something to our present knowledge of the stellar universe.

THE VELOCITY OF METEORS AS DEDUCTED FROM PHOTOGRAPHS AT THE YALE OBSERVATORY.

BY W. L. ELKIN.

The instruments in use at the Yale Observatory for the photographic observation of meteors have been equipped with an arrangement for the determination of the velocity of meteors. The idea of using photography for this purpose seems to have first been suggested as long ago as 1860 by J. Homer Lane, the well known physicist and discoverer of 'Lane's law.' In 1885 a well planned attempt in this direction was made by Zenker, in Berlin on the occasion of the expected shower of Andromedids, but apparently without success, and lately the suggestion has again been made by Professor Fitzgerald.

The Yale apparatus consists of a wheel (a bicycle wheel) rotating in front of the cameras and carrying a number of opaque screens. There are at present twelve of these interceptors and the rotation is effected at the rate of thirty to fifty turns per minute by means of a small motor worked by three or four bichromate cells. It will be advisable to increase the number of occultations in the future, however. At each revolution a record is made at the chronograph so that the wheel's velocity at any instant is always known.

The length of the interruption of a meteor trail and the resulting velocity are easily derived from the plates, if the meteor is also recorded on a plate at our second station at Hamden, distant about three kilometers. The first attempt was made at the August period last year, and subsequent ones at the Leonid, Andromedid and Geminid epochs in November and December last. In all so far five such trails have been obtained with corresponding records at Hamden and the time and identification also secured. These have been carefully measured and reduced and the resulting data are brought together in the following table of which the headings explain themselves sufficiently:

Meteor No.	Date 1899	Greenwich Mean Time	Apparent Radiant 1875.0 R. A.	Decl.	Apparent Velocity (km per sec)	Approxi'ate Altitude (in km.)
1	July 31	17h 4m 30s	28° 55′	+ 57° 31′	50.4	88 to 75
2	Aug. 7	14 25 25	288 12	— 6 20	12.2	50 to 45
3	Aug. 8	16 32 47	43 55	+ 56 33	50.3	101 to 94
4	Nov. 24	16 31 25	27 43	+ 40 33	20.2	93 to 90
5	Dec. 12	21 43 0	113 44	+ 33 36	36.5	90 to 96

If we now correct the values for the apparent radiant and velocity for the effect of the attraction of the earth and its diurnal rotation by Schiaparelli's formulæ, we derive the 'corrected' radiant and velocity, in the following table and hence the 'true' velocity of the meteors relative to the sun. The last columns of this table contain the 'true' and 'apparent' velocities which a parabolic orbit, or, in the case of the November 24 meteor, an elliptic orbit of 6.62 years period should have produced.

Meteor No.	Corrected Radiant 1875.0 R. A.	Decl.	Corrected Apparent Velocity. (km. per sec.)	True Velocity (km per sec.)	Parabolic or Elliptic Velocity (km. per sec.) True	Apparent
1	29° 50′	+ 57° 40′	49.1	34.4	41.8	58.3
2	289 44	— 27 58	5.0	32.0	41.8	27.1
3	45 12	+ 56 35	49.0	32.4	41.8	60.3
4	23 52	+ 39 46	16.8	39.8	39.3	19.6
5	112 22	+ 33 2	34.7	34.0	42.4	49.5

A comparison of these two last columns with the corresponding ones of the observed values shows that except in the case of the Andromedid meteor on November 24th, both the apparent and true observed values of the velocity are much smaller than those derived on the assumption of a cometary velocity. The former (the observed) velocities lead to orbits of a very improbable character having periods of from 1.25 to 1.80 years, so that it would seem an almost certain conclusion that the atmospheric retardation has amounted to from eight to fifteen kilometers per second for the four meteors. On the other hand the Andromedid of November 24th furnishes the following orbit, by side of which is placed that of Biela's comet according to Hubbard:

Meteor Nov. 24, 1899.		Biela's Comet.	
$\pi = 108^\circ\ 48'$	1875.0	$\pi = 109^\circ\ \ 8'$	1852.0
$\Omega = 242\ \ 22$		$\Omega = 245\ \ 51$	
$i = \ 12\ \ \ 4$		$i = \ 12\ \ 33$	
$e = 0.7923$		$e = 0.7559$	
$a = 4.110$		$a = 3.526$	

Rather unfortunately this Andromedid trail is at the very edge of the plate, and therefore somewhat ill-defined, so that the length of the single interruption available is somewhat uncertain. If this be changed by 19″ from the original measurement, or about 1/15 of a millimeter on the plate, a quantity which is, perhaps, admissable under the unfavorable circumstances, an exact agreement with the cometary elements *a* and *e* can be brought about.

This remarkable circumstance makes it, therefore, again somewhat questionable whether the small velocities found for the other four meteors may not after all be somewhere near the cosmic values and the truth will have to await accumulated evidence. Especially valuable will be a long trail with considerable change in altitude and a large number of sharp interruptions. The only one of our trails which has more than two such breaks is the one of August 7th, where three values of the velocities can be deduced. These are, in the order of the meteor's progress, and descents, 12.33, 12.11 and 12.09 km. per second, which, while showing an increased retardation, hardly admit of any definite conclusions. As I have just said, more data are necessary and we hope to secure them and also increase the accuracy in the near future.

RECENT ASTRONOMICAL WORK AT COLUMBIA UNIVERSITY.

BY HAROLD JACOBY.

Professor Rees, director of the Columbia University Observatory, being absent at Paris as a member of the international jury for instruments of precision, it devolved upon Professor Jacoby to present a very brief account of Columbia's research work in astronomy during the past year. The University possesses no adequate observatory, so that the work in observational astronomy has been perforce confined very largely to the measurement and discussion of celestial photographs. The only long series of direct observations upon the sky itself is that made during the last seven years with the zenith telescope by Professors Rees and Jacoby and Dr. Davis, who was a member of the observatory staff until last year. This series of observations was discontinued in May, 1900, because a similar one, upon a much more extensive scale, has been commenced by the International Geodetic Association. It is hoped that the Columbia observations, together with a corresponding set made at Capodimonte, Italv, will furnish a valuable contribution to our knowledge of the constant of aberration and the variations of terrestrial latitude.

The measurement and discussion of astronomical photographs has included work upon Rutherfurd negatives and upon negatives made at Helsingfors, Finland, and at the Cape of Good Hope. In connection with the Rutherfurd plates, the observatory has just published Dr. W. C. Kretz' paper on the 'Stars in the Coma Berenices Cluster.' This paper was offered by Dr. Kretz last year as his dissertation for the degree of Ph.D. It will be distributed very soon. Dr. G. N. Bauer's paper, also a dissertation for the degree of Ph.D., contains a determination of the parallax of μ Cassiopeiæ from Rutherfurd measures of position angle. It is now in course of publication, as is also a paper by Professor Jacoby on the 'Pleiades.' This latter contains the results of further computations that have been made in recent years, using the same Rutherfurd measures discussed in Professor Jacoby's former paper on the 'Pleiades,' published in 1892. The new discussions bring out the excellence of Rutherfurd's work even more clearly than before. Several other sets of Rutherfurd star plates have been measured and reduced, but it has not yet been possible to prepare the results for printing.

An attempt was made last year to photograph the November meteors, and one trail was secured by Mr. C. A. Post and Professor Rees, at the former's observatory in Bagport.

Dr. Caroline E. Furness has completed the discussion of four photographs of the stars immediately surrounding the north pole of the sky. These photographs were made at Helsingfors some years ago, and measured at the Columbia University Observatory. Dr. Furness has deduced from these measures a photographic catalogue of precision including the stars within one degree of the pole, and has been able to show also that the optical distortation of the Helsingfors telescope is confined within very small limits, so far as such distortion depends on position angle. These researches are in course of publication by the observatory of Vassar College, and have formed the subject matter of a dissertation for the degree of Ph.D., conferred upon Miss Furness this year at Columbia University.

A similar series of negatives of the south pole was made some years ago at the Cape of Good Hope, and these have been in course of measurement during the past year at Columbia. It is hoped that they can be completed during the present summer, and that the results can be computed and published within a year.

The attempt to secure an independent determination of the constants of nutation and aberration by photographing close polar star trails has made considerable progress. A special 'fixed' polar telescope has now been mounted by Dr. Donner in a suitable new building at Helsingfors, at which place it is intended to make the observations, in order to take advantage of the high altitude of the pole, and the consequent diminution of atmospheric refraction. This fixed telescope will be used with the object glass of the present Helsingfors astro-photographic refractor. We shall thus secure the important advantage of using a glass whose optical distortion has been most carefully investigated. It is hoped that the actual work of making the negatives can begin at Helsingfors as soon as the nights become a little longer, and that measurements can commence at Columbia before the year is out.

PHOTOMETRIC OBSERVATIONS OF THE ASTEROID EROS.

BY HENRY M. PARKHURST.

My simple formula for the diminution of the light of an asteroid in proportion to the angle at the asteroid between the sun and the earth, seems to be substantiated by Professor Müller, within ordinary limits, but the new asteroid Eros extends the angle so far as to create uncertainty. For the old asteroids the extreme value of this angle seldom exceeds thirty degrees; whereas its smallest value with

Eros in the present opposition is only twenty-eight degrees, and its greatest value more than twice that amount. In the observations of the oppositions of our moon the formula of simple proportion is appreciably changed before reaching that extent. If the formula depends upon the diminution of light in arithmetical progression, the variation is in one direction, whereas if it depends upon diminution of light measured in magnitudes, or in geometrical progression, the variation is in the opposite direction. It has seemed to me desirable that special pains should be taken to observe Eros photometrically, in order to learn what we can of the true law of diminution, and if possible its cause.

I desire especially to call attention to this desirability, for the reason that a tall building is in process of erection so close to my observatory that should it be completed early in the present year, it may prevent my photometric observation of Eros at the times essential to this investigation; in which case we must rely wholly upon such observations as may be made elsewhere. I had already made preliminary observations in anticipation of this investigation before the building was commenced; and I still hope that I may be able to complete my work before my observation of that part of the sky is cut off.

STANDARDS FOR FAINT STELLAR MAGNITUDES.

BY E. C. PICKERING.

It is believed that the following extract from the report of Professor Cross, the Chairman of the Rumford Committee of the American Academy, will be of interest to members of the Astronomical Society.

An appropriation of five hundred dollars has been made from the Rumford Fund to be expended under the direction of Professor Pickering, for the purpose of carrying out an investigation on the brightness of faint stars by co-operation with certain observatories possessing large telescopes. This appropriation results from a communication made to the Council of the Astronomical and Astrophysical Society of America held in New York last January. It was represented that the most urgent need of astronomy in America was adequate endowment of the great telescopes of the country so that they could be kept actively at work. It was shown that while the two largest telescopes of the country, and of the world, were kept constantly at work the means for the reduction and publication of the observations is wholly inadequate, while some of the largest telescopes in the country, representing a plant costing hundreds of thousands of dollars, are nearly idle and therefore useless. Observations of the greatest value can be obtained with these instruments at small expense, and it is hoped that the beginning now made will justify its permanent continuance on a large scale. The problem undertaken is the determination of the light of faint stars, selected as standards. These will furnish points of reference to which other photometric measures may be referred. Five photometers have been constructed in which by interposing a photographic wedge of shade glass, an artificial star is reduced in brightness until it appears equal to a real star, as seen in a large telescope. Thirty-six regions have been selected in different parts of the sky, in each of which a series of standards is to be measured. Five stars of about the twelfth magnitude, five of the fifteenth, five of the sixteenth, and five of the seventeenth, are to be chosen in each of these regions. The faintest stars will be selected and measured with the Yerkes forty-inch and Lick thirty-six-inch telescopes. Those of the sixteenth magnitude will be measured with the twenty-six-inch telescope of the University of Virginia and perhaps the Princeton twenty-three-inch telescope. The stars of the fifteenth magnitude will be measured with the fifteen-inch Harvard telescope. All of the stars will be compared with the stars of the twelfth magnitude, whose absolute magnitudes will be determined with the twelve-inch Harvard meridian photometer. Their relative brightness will also be determined more accurately with the Harvard fifteen-inch telescope. After the work is fairly started it is believed that it can be reduced to a simple routine, by which great results may be attained with a moderate expenditure. By the time this report is presented it is expected that observations with the Yerkes, Lick, University of Virginia and Harvard telescopes will be in progress.

REGISTRATION OF ASTRONOMERS.

BY E. C. PICKERING.

A plan for the registration of astronomers desiring positions was proposed to the Society at its meeting at the Harvard Observatory in 1898. It was hoped that in this way suitable candidates could be found for vacant positions, and at the same time good positions could be found for those qualified for them. As however, the members present did not desire that the Society should undertake this work, it has been carried out by, and at the expense of, the Harvard College Observatory. Blanks of the form appended have been distributed, and during the last eight months, thirteen men and six women have applied for positions. Requests for assistants have been received from four institutions, but in only one or two cases were the vacancies filled. The number of candidates for positions is therefore abundant and it is hoped that institutions will avail themselves more freely of this register in filling positions. No charge is made either to institutions or individuals, and, if desired, communications are regarded as confidential.

PHOTOGRAPHS OF NEBULAE AND STAR CLUSTERS OBTAINED WITH THE CROSSLEY REFLECTOR.

BY J. E. KEELER.

The photographs on glass were exhibited by Professor Campbell, who called attention to some of the difficulties which had to be overcome in the use of the instrument and to the important results established, that nebulæ as a rule are spiral in form and as an exception irregular in form.

SOME NEW SPECTROSCOPIC BINARIES.

BY W. W. CAMPBELL.

A list of half a dozen spectroscopic binary stars, recently discovered by Messrs. Campbell and Wright at the Lick Observatory. (Published in the *Astrophysical Journal,* Vol. XII, p. 254).

A SIMPLE METHOD OF INSERTING THE COMPARISON SPECTRUM IN SPECTROGRAPHIC OBSERVATIONS.

BY W. H. WRIGHT.

The length of the slit is limited by two total reflection prisms mounted immediately in front of the slit plate. The reflecting edges of the two prisms are parallel to each other and at right angles to the slit; and the distance between the reflecting edges is the length of the slit. The artificial light, from two sets of electrodes placed one near each end of the full-length slit, enters the slit through these prisms near their vertices. The method possesses many advantages.

COLOR SCREENS AS APPLIED TO ACHROMATIC TELESCOPES.

BY GEORGE H. PETERS.

Attention was called to the want of definition caused by the secondary spectrum in large refractors. It was then shown how this was removed at the U. S. Naval Observatory by adapting a cell filled with an absorbing solution between the eye-piece and eye of the observer in the twenty-six-inch telescope. The thickness of the absorbing layer is about six millimeters, and the solutions used are the following:

1. Picric Acid and Chloride of Copper dissolved either in water or alcohol, for cutting out the red and blue light.
2. Picric Acid dissolved in alcohol or water.
3. Bichromate of Potash in water.
4. Chromate of Potash in water.

Solutions 2, 3 and 4 remove the blue and violet light. Alcohol is used in cold weather. The absorption of the liquids is tested by a direct vision spectroscope.

Some of the benefits derived from the color screen are:

Improved definition on planets and satellites and in certain classes of double stars.

In observations of objects by day where the blue light from the sky is removed.

Professor See and Mr. Peters are jointly credited with this device. (See *Astronomische Nachrichten*, No. 3636).

THE SPECTROGRAPHIC DETERMINATION OF THE MOTIONS OF THE STARS IN THE LINE OF SIGHT.

BY W. W. CAMPBELL.

Complying with the Council's request for a paper on this subject, the following points were presented:

The great interest taken in this problem is attested by the fact that the largest refracting telescopes in the United States, France, England, Germany, Russia and Africa are, or soon will be, largely devoted to the determination of stellar velocities.

It must not be assumed that, because a thirty-six-inch objective receives nine times as much light as a twelve-inch, it will be able to carry velocity determinations in that ratio to the fainter stars. The larger telescope is accompanied by stronger absorption of the light, by larger stellar images (except in perfect seeing), by greater difficulties in guiding, etc.; so that it is able to extend the work of a twelve-inch telescope only five to seven-fold. A thirty-six-inch reflector, suitably mounted, and in a dry climate, would probably be more efficient than a thirty-six-inch refractor in this problem.

Success in determining stellar velocities depends upon a great many elements, of which the following were all that time permitted a mention.

I. A suitable compromise between the various optical and mechanical features—many of which conflict—to secure a powerful and efficient spectrograph.

II. Suitable prisms and lenses. The requirements demanded by the line of sight tests are so severe that satisfactory lenses and prisms are difficult to obtain. Since a change to a new prism-train usually requires many changes in the mounting, the prisms should be constructed and thoroughly tested before the rest of the instrument is designed.

The day for using the ordinary double camera lens is past. Even the triple lenses do not fulfill the difficult spectrograph's requirements.

III. Absence of differential flexure during the exposure time: the optical angles must remain constant. This is very largely a problem in mechanical design. The elimination of appreciable flexure effects during long exposures is difficult, but not impossible. Existing spectrographs, including those just now completed, are wrongly designed, in that they are supported only at one end. The heavy prism end projects out into space, unsupported. The spectrograph is held out 'at arm's length,' so to speak. Now the spectrograph is an instrument complete in itself, and need not be rigidly connected with the telescope tube. A framework connected with the telescope could be arranged to support the spectrograph, in position, both near its upper and its lower ends; care being taken that strains in the supporting framework should not be communicated to the spectrograph. This form of support would permit a more economical distribution of material in the spectrograph, and should decrease the flexure effects several fold.

IV. The Mills spectrograph has been enclosed in a wooden box case, lined with thick hair felt, carrying on its interior surface about thirty feet of German silver wire. As the temperature within the case falls, a storage battery is connected with the resistance wire. The heat generated tends to keep the instrument, and especially the prisms, at a constant temperature—a most important desideratum.

V. An accurate method of guiding during the exposure.

VI. The use of the finer dark lines throughout the spectrum, rather than of the heavier lines which have heretofore been the ones measured.

VII. Long experience in making the measures.

An exposure of one hour is required for a star of the fifth photographic magnitude, as given in the *Draper Catalogue.*

At the Lick Observatory two or more plates have been secured for each of about three hundred stars. For the best stars, such as Polaris, the probable error of a single determination of velocity is about one-third of a kilometer per second. For such stars the plates seem to be essentially perfect, and to secure greater accuracy it appears that a more powerful spectrograph is required.

Even with perfect plates the observer must be on his guard against systematic errors arising from changes in his personal habit of measurement.

Of the three hundred stars observed, twenty-two have been found at the Lick Observatory to be binary, in addition to three previously detected from the same list by Belopolsky. This leads us to the important conclusion that one star in twelve is a spectroscopic binary. And it is probable that others of the stars observed are binaries as yet undetected.

SOME PECULIARITIES IN THE RADIAL VELOCITY OF ζ GEMINORUM.

BY W. W. CAMPBELL.

This is a well known variable star, period of ten and one-sixth days. Its velocity in the line of sight was found, independently at Pulkowa and Mt. Hamilton, to be variable. Forty-five observations at Mt. Hamilton, distributed over one and one-half years, left no doubt that this star is a spectroscopic binary, and that the variation in brightnes is produced by the companion. The eclipse theory is untenable. The variation is probably the result of tidal action between the two bodies.

The observed velocities cannot be represented by elliptic motion. Drawing the elliptic curve which best represents the observations, the observed curve is alternately above and below it, crossing it at intervals of about forty-one hours. Three complete periods of the minor irregularities coincide with one light period. These minor irregularities in the observed velocities are probably due to minor tidal effects in the star's atmosphere. (Published in the *Astrophysical Journal*, Vol. XIII, p. 90).

H. M. Paul. I would like to ask if these observations were plotted to represent all the observations, obtaining the period from these observations.

Mr. Campbell. They were all plotted with reference to the brightness of the star assuming the old period. There is some doubt as to the exact form of the light-curve. I have endeavored in every possible way to ascertain the form of the light-curve; but there seem to be some irregularities, and I think that extremely accurate observations would show that the brightness curve has the same irregularities as the velocity curve; that there is a reflex action of one upon the other.

Mr. L. E. Jewell. Mr. Campbell has suggested that the irregularity in the motion in the line of sight may be due to tidal action, which I think is probably the case; but he has also suggested that it may be due to tidal compression, which I do not think can explain the phenomenon. I have myself been engaged in some work bearing upon that problem, and among other things the pressure of the different layers of the solar atmosphere; but the lines which have been measured in the solar atmosphere do not have a pressure of more than one and one-half atmospheres, considering the pressure of the earth's atmosphere as one. The variation due to difference of pressure would be too slight to produce the effect that he speaks of. I think it probable some tidal action causes the motion in the line of sight, and that it is not due to change of pressure, because the differences of pressure would be too slight to produce such an effect. In the case of the sodium lines in the sun's atmosphere, the actual pressure is only about an atmosphere and a quarter. The variation in the hydrogen lines would be very small, and it is probably produced in a higher layer of the sun's atmosphere.

Mr. Campbell. We seem to have no analogous case to this star from which to obtain data to explain it. We have no knowledge of tidal action elsewhere, but here we seem to have enormous evidence of tidal action.

T. J. J. See. I think the explanation of the cause of the second curve superposed upon the first curve is very probable. In the case of the ocean tides, we have very little vertical motion and a horizontal motion many times greater. The distortion shown in the figure indicates that the horizontal motion is very large.

W. J. Humphreys. Some work has been done by Wilsing at the Potsdam Observatory, showing a great change from change of pressure; but he applies this to such stars as Nova Aurigae. He has obtained results, working with hydrogen, showing that the spectrum lines in hydrogen are very sensitive to diminution of pressure. This applies especially to the deeper lines. He has obtained perfectly sharp lines with a pressure of fourteen atmospheres.

Mr. Jewell. From our knowledge of the solar spectrum it is perfectly certain that the lines do not show any evidence of powerful pressure. Under such pressure the lines would probably be broader.

THE INDIAN ECLIPSE PHOTOGRAPHS OF JANUARY 22, 1898, OBTAINED BY THE LICK OBSERVATORY EXPEDITION.

BY W. W. CAMPBELL.

Photographs of the corona and its spectrum; and of the spectrum of the sun's edge, were thrown on the screen. Special attention was called to the apparent and probable connection between the prominences and the curved coronal streamers enclosing them and to the relative displacement of the bright and dark lines in the spectrum of the sun's edge.

GENERAL DISCUSSION

TOTAL SOLAR ECLIPSE OF MAY 28, 1900.

The report of the Eclipse Committee was presented by Professor Newcomb. Then a general discussion took place of the observations of the total solar eclipse of May 28, 1900, as follows:

W. W. Campbell. Being a long distance from our base in California, it was impossible to take our plates home for development, and they were developed in camp, where it was impossible to do photographic work successfully. I have brought one of the original negatives, but Mr. Brown should have the privilege of presenting it. It was taken with an exposure of one second, with a forty-foot camera. It reveals the fact that the coronal tails were not so numerous as those in 1898, while those were not so numerous as in 1893. There seems at first to be no connection between the coronal streamers and the prominences; and yet, if you will go over it carefully, I think you will see there is some connection between them. Our spectroscopic material was not so great as we should have liked to obtain; but for the third contact we obtained very satisfactory results. It was a question whether bright lines would be shifted toward the red end, but they seem to show no evidence of such shifting.

S. J. Brown. The eclipse observations of the Naval Observatory were widely distributed and covered a great deal of ground. Two main stations were occupied, one in North Carolina and the other in Georgia. Our photographic work is not in a condition to exhibit. There was one experimental line of research I think it worth while to mention. We wished to try experiments with color screens; and with one lens we used isochromatic plates, and with another lens the ordinary photographic plates, to see whether any indications would be shown as to a difference of structure of the corona due to the green line. The result showed no difference of structure, but there seems to have been a greater expansion of the polar rays when we used the color screens than when we used the ordinary plates. Photographs were taken to obtain as great an extension of the corona as possible; but the sky was not favorable, and we did not obtain so great an extension as was shown by the results in India. The spectroscopic work occupied our most serious attention. We had some very rare gratings, ruled to concentrate the light of the first order at a special point. Two of these gratings, from the Johns Hopkins University, were utilized, one at Pinehurst and one at Griffin, besides another grating of long focal length. Our preparations for this work were much hurried, but we had gratings of which the curves were carefully computed for the focal length of the quartz lenses. At Griffin we obtained a reversing layer of eight seconds. Mr. Jewell has brought some copies of the only successful plates at Pinehurst, showing several new coronal lines, one coinciding with the 1474 line, and there were three other new lines. Dr. Dorsey of the Johns Hopkins University also took photographs, and Dr. Wood of the University of Wisconsin undertook to study the shadow bands which precede and follow the eclipse. He is not here, but he thinks he has reached a satisfactory conclusion with regard to the cause of the shadow bands. While our results in spectroscopic work were disappointing, in view of the large outlay, they seem to vindicate the value of that method. We think we shall be able to obtain a plate which will bend to the required curvature, and thus be able to photograph the reversing layer.

L. E. Jewell. We obtained a different wave length for the bright and for the corresponding dark lines; and I think that difference in wave length is caused by the fact that the dark lines were produced very close to the moon's edge, by the remaining portion of the crescent, not covered by the moon, while the bright lines were produced further out. On one of the photographs taken at Pinehurst there is a very distinct difference of the H and K lines, between the bright and dark portions of the spectrum. The bright line is displaced with reference to the dark line in the direction outside, or further away, from the sun itself, just as it should be if that were the true explanation. In determining the method we should follow in the use of these plates we were largely influenced by the results of Evershed in India in 1898, showing that the chromosphere and reversing layer were much brighter in the upper part, showing other interesting phenomena. Another interesting thing was the presence of the rare element scandium. It was thought best to use his grating for the purpose of our work, and I made comparisons showing that he used a dispersion about three times that of a single prism; and we concluded that we could obtain at least as much light from our grating as from a prism. Our results at Pinehurst were thought of extreme importance. With an exposure of only one second we obtained results showing that if we had been able to bend the plate to the required focal curvature it would have given us a spectrum from wave length 3000 to 6000, giving us 1300 lines; the effect being very sharp lines in the neighborhood of the H and K calcium lines, and pictures of the chromosphere proper and the reversing layer showing fifty to seventy-five prominences. The difference between the calcium and the hydrogen lines was shown very prominently indeed. A plate out of focus showed the yellow sodium line, and the coronal line at 1474 which were seen much stronger on the opposite side of the sun from that where the ordinary bright lines are seen. This green line was much brighter than on the western side of the sun. There is no line which seems to be evenly distributed on the two sides of the sun. The green line seems to be gathered into a very short arc on the western limb. On another plate taken twenty-five seconds later, the exposure was five or six seconds, and on that these coronal lines are shown all the way round. There are four lines not obtained before, the substance producing them seeming to be about the same as that giving the green lines. They show the strongest at some distance from the sun's surface, say three to five thousand miles above the solar surface, although they are visible close to the solar surface. Another interesting thing was the beautiful way in which the carbon band showed with an exposure of one second. It was very strong a hundred miles from the solar surface. One word with reference to future work: I think it is very desirable to use a concave grating in the ordinary way, but instead of using a dense lens of quartz, to use a very large concave reflector of a focal length of 100 to 150 inches, which would give an image of the sun an inch and a half in diameter; and then we could use a wide open slit so as to be certain to get the limb of the sun inside of it. At Pinehurst we had to cut down the slit in consequence of the curvature, and had an image of the sun only a third of an inch in diameter to work with. In future work much the best plan will be to use two concave mirrors, one of a short focus for the dense lines, and the other of a considerable focal length, the slit being placed between them. In this way we can let the light come through the narrow slit, and then the larger and long focus mirror will act as a condenser, and there will be no disturbance whatever in the focus. A telescope of high power should be used, and focused very carefully; and the light reflected from the second mirror would give us parallel light; and if the adjustments were well made the image would be very sharp. By that method we ought to be able to obtain very satisfactory results.

Winslow Upton. I will report briefly the work we did near Norfolk by very ordinary astronomical and photographic processes. We had a four-inch telescope for visual work; and we had an equatorial stand upon which a camera was carried by clockwork. The camera contained two very long focus lenses. We also had four ordinary cameras, which we used for the purpose of obtaining the extension of the corona. We found that the duration of the eclipse was shorter than calculated. By the English and the American Ephemeris it was 101 seconds, while we made it 99 seconds. In the visual observations we used a magnifying power of fifty or sixty. At the time I did not notice the hooded arrangement of the corona, this gigantic hood overlapping the strata, shown in the photographs of the eclipse of 1878. In our observations to determine the place of the moon, and in the search for an intra-Mercurial planet, we carried out the instructions of Professor Pickering, which were to expose for sixty seconds. Our cameras covered a range about 25° along the sun's equator, and with eight or ten gigantic plates we covered that region; but we got nothing except one or two bright objects, possibly only the planet Mercury, and there seemed to be star trails instead of images, perhaps from a fourth magnitude star. I think the exposure might have been longer; for I feel confident that we could have exposed eighty or ninety seconds without fogging the plate. For the spectroscopic work we used triple-coated plates, especially made for us by the Seed Co., and also orthochromatic plates. With regard to the development of the plates we decided to vary from the instructions of the committee. The instructions were that we should use an exceedingly weak developer and develop a long time. Professor Pickering on the other hand recommended a strong developer, and a great deal of bromide. As we had duplicate plates we decided to try both plans, and I think on the whole that we obtained better lines with the strong developer and the bromide restainer. I have here some lantern slides which I will show.

Ormond Stone. The University of Virginia took part in the eclipse observations at Waynesborough, N. C. We used a forty-foot camera. I desire here to express my gratitude to Professor Campbell for the advice he gave us at the beginning, and for his kindness in assisting in the preparations, and also in developing our plates for us. Our preparations were begun very early and we went to the camp about a month before the eclipse took place. At the time of the eclipse the sky was perfectly clear, and we took a very good series of pictures, showing a vast amount of detail clear down to the sun. We have learned much of what ought to be done in the future. Eclipse problems are constantly changing and new methods are used. In the adjustment of the frame in position, I think it ought to be done by actual observation of the stars, rather than by experiment. We happened to get our carriage some inches out of place, but by our observations we brought it within one-sixteenth of an inch of its true place. We may study the photographs as to the forms of the filaments, and the relations of the chromosphere to the protuberances; but that ought to be supplemented by visual observations with the telescope. A six-inch telescope with a magnifying power of fifty will show us ten times as much as can be seen in the best photographs. But the observer sees it and nobody else, so that we still need the photographs. The plates were exposed by Mr. Mayo, who had himself constructed the apparatus. Mr. Morgan had a four-inch equatorial, and I used a six-inch equatorial and observed visually. It was our purpose to examine each of the prominences in succession to see if we could perceive any distortion. We could see no relation to the protuberances, and our visual observations simply confirmed what was shown in the photographs. At the eclipse of 1878 the filaments were well seen, and each one stood out distinctly. At this eclipse there was not that sharpness, and there seemed to be a strong background something else to the equatorial filaments. In 1878 at the poles the rays were very much as in this eclipse. In the equatorial region there was a perfect network of filaments. They started out and moved right back with an incurvature in the opposite direction, so that there were a number of filaments side by side. They are certainly not hyperbolic curves, but we do not know what they are. One suggestion is that they are meteoric or comet streams. Our exposures were mostly short; we had nothing exceeding twelve seconds. It would seem well to have some longer exposures. I am glad the Naval Observatory has secured a plate with a longer exposure, on which we can see longer filaments and learn more of the nature of the curve. By tracing the curve back to the sun's surface we may be able to get some idea of its form. We had a number of small cameras mounted on a polar axis and managed by Mr. Lyon, and with these we used a color screen such that the green line was not seen, but on an open space. I think in another eclipse we ought to get more color screen pictures with our large cameras.

Mr. C. G. Abott presented a report of observations at Waynesborough.

Mr. Dorsey explained the mode of determining the polarization of the bright coronal lines.

The Secretary read the following reports from Edwin A. Frost and E. E. Barnard upon their observations of the eclipse made at Wadesboro, N. C.

E. B. Frost. Four spectroscopes were employed: I. A small plane grating in front of a lens of two inches aperture and twenty inches focus, for visual use in determining proper instant for exposure for obtaining the "flash spectrum."

2. Train of three large flint prisms, at minimum deviation for λ 4230, in front of photographic lens of 3½ inches aperture and 42 inches focus; for photographing flashes and cusps and coronal spectra.

3. Small concave grating used directly, without slit; focus 30-inch for photographing flash spectra.

4. Large plane grating of 20,000 lines to inch, in front of visual lens of 3½ inches aperature, 42 inches focus, with red screen, for photographing red end of spectrum of cusps, flash and corona. All placed in horizontal beam thirteen inches in diameter reflected from cœlostat. Time called by Professor A. S. Flint; exposure of two and three operated by Dr. G. S. Isham of Chicago; signal for exposure given by visual observation of flash with one by E. B. Frost, who operated four.

Results: 1. The flash sectrum was visually observed in the yellow near D_3 at second and third contacts. The number of lines seen, however, was not as large as might have been expected; some twelve or fifteen were seen in the small field employed. These were broken by the promininences, and were doubtless chiefly lines of the usual chromospheric spectrum. No attempts at measurements were made, as the object of the visual observations was to find the instant for making the exposures for flash spectra. The dark lines of the cusp spectrum were sharp and distinct forty-five seconds before the computed time of totality. A glance into the eyepiece at the middle of totality showed no coronal rings in the field, which did not include the region from the coronal line 1474 (λ 5317) to K (λ3934).

2. Objective train of three large prisms (mean path of the rays

in the glass was eight inches). Five exposures were made, on two plates, all of which were successful.

(*a*) The two spectra of the cusps, taken before and after totality, show many bright (chromospheric) lines in addition to the dark lines. The region covered by the plate was necessarily limited, by the construction of the plate holder, and includes only from λ 4380 to λ 4025. Fifty bright lines were measured on the second cusp spectrum.

(*b*) The first flash spectrum shows no continuous spectrum, but will furnish the wave-length of many bright lines. Something over one hundred lines appear to be measurable within the above limits.

The second flash spectrum was overlaid by a band of solar spectrum, the third contact occurring some seven seconds earlier than was expected and indicated by the count. This plate, however, shows a large number of bright lines, two hundred and seventy-five having been measured on it by the writer between λ 4380 and λ 4027. Young's list of chromospheric lines contains twenty-seven in that region.

(*c*) The coronal exposure was thirty seconds, but could have been longer to advantage. The rings of $H\gamma$ and $H\delta$ (chromospheric) are strongly impressed, showing the prominences, and next in intensity is the strong chromospheric ring of wave-length λ 4078. Four other rings are seen in whole or in part, the coronal ring at λ 4231 being next in intensity, although faint. It shows none of the broken appearance which characterizes the chromospheric rings. Another ring of longer wave-length than $H\gamma$ may also prove to be coronal. The continuous spectrum of the corona is quite strong. This plate has not yet been accurately measured.

3. The small concave grating, without slit, was used for first and second flash.

On the first some seventy lines (bright) are shown between $H\beta$ and $H\delta$; on the second about one hundred and ten in that region, with about fifty others less sharply in focus, chiefly on the violet side of $H\delta$.

4. With the limited time for exposure, the sensitiveness of the plates, of the 'Erythro' brand was insufficient to record the flash spectra. The plate exposed for sixty seconds to the corona shows no impression, as was indeed expected. The spectrum of the cusp ten seconds after totality shows some dark lines and a few bright lines, and the second flash spectrum is seen in traces.

E. E. Barnard. The following preliminary statement concerns the photographs of the corona obtained by the Yerkes Observatory expedition to observe the total eclipse of the sun at Wadesboro, North Carolina, May 28, 1900.

The weather conditions were as near perfect as possible.

The most important instrument was a 61½-foot horizontal cœlostat with an excellent six-inch photographic objective made specially for the purpose by Brashear. The light was thrown into the telescope by a very perfect plane silvered mirror made by Mr. Ritchey for the instrument. The equatorial mounting that carried this mirror was also made under Mr. Ritchey's direction though not for this special purpose. It was, however, adapted by him for a forty-eight-hour revolution. This instrument was driven by the clock from Professor Hale's twelve-inch equatorial. The mounting also carried a fifteen-inch mirror for Professor Frost's spectroscopic work.

A long horizontal tube connected the six-inch objective with the photographic house. This tube consisted of a wooden frame work covered with red water proof paper and was whitewashed on the upper part. A white cloth covering was also placed over it with a few inches of air space between the cloth and the tube. Frequent diaphragms were put along the inside of the tube to prevent stray light or reflections.

The photographic house in which the plates were to be exposed, was about thirty feet by six feet; it was of wood made thoroughly light proof by heavy red paper.

The plates were placed in a carrier fifteen feet long, which ran on ball bearings in a light-tight sheath—the exposures being made through an aperture in the sheath where the image fell.

With this carrier, by rapidly shoving it along, one plate after another could be substituted for exposure with the minimum loss of time, about four seconds for a change. With it seven plates were exposed. Three of these were 14x17 inches, and the other four 25x30 inches. The following exposures were given these plates.

No.	Exposure.	Size of plate.	Kind of plate.
1	½^{s}	14 x 17	Cramer double-coated.
2	2	14 x 17	Cramer Crown.
3	8	25 x 30	" "
4	30	25 x 30	" "
5	14	25 x 30	" "
6	4	25 x 30	" "
7	1	14 x 17	Cramer double-coated.

A stop, regulated by hand, fixed the position of the carrier at each exposure, so that the image should always fall central on the plate. The plates were all set parallel to the celestial equator.

The exposures were made by a wooden exposing shutter, with a round aperture on one end of it. This shutter was controlled by two cords, one from each end, running into the photographic house. These cords being held taut, one in each hand, the exposures were made with absolute certainty and rapidity, by a quick pull with one or the other hand.

In the actual work, the carrier containing the plates was moved forwards by Mr. Ritchey after each exposure. At his signal 'ready' the proper exposure was given by me, the time being counted from a sounder beating seconds.

The seven plates were exposed without a hitch, the program being successfully carried out.

The signal for the beginning of totality was given by Mr. Putnam of the U. S. Coast and Geodetic Survey, who observed the contacts with a telescope at the Smithsonian Station, a hundred feet or so distant.

The exposures were begun immediately upon the signal for totality. A signal was also to be given ten seconds before the close of totality. This last signal was heard while preparing for the last exposure, and certainly within three or four seconds of this the exposure was made; the sun was then just appearing as a small speck of light—the end of totality having apparently come sooner than was expected.

At each exposure the image was seen on the plate and I was at once impressed with the striking likeness it bore to the corona of January 1, 1889. Though the moon appeared very black on the plates, the corona itself was disappointingly feeble. In the casual inspection, during exposure, the prominences were not noticed and but little detail was visible.

On the night before the eclipse each plate had been carefully backed with a non-halation solution consisting of caramel and burnt sienna. The plates were at once placed in the carrier ready for exposure.

In preparing for the eclipse the question of sensitiveness of the plates to be used was carefully discussed with Professor Hale and we finally decided to use the most sensitive plates. The result justifies our decision and shows that with a long focus instrument like this (1/123) the plates cannot be too sensitive.

Two of the plates were Cramer double-coated and were supposed not to be so sensitive as the Cramer Crown. Plate No. 1 (double-coated) was purposely left unbacked. No. 7 was also double-coated and backed.

Up to this writing, plates No. 2, 5, 6 and 7 have been developed. They are remarkably sharp and perfectly defined, and show the prominences and inner corona very beautifully. The polar fans come out magnificently. There is a great deal of beautiful detail in the inner corona that promises richly to repay careful study.

Great care is being exercised in the development of the plates to insure not only detail near the sun but to get also as great extension as possible.

Other instruments used were a six-inch and a three and one-half-inch portrait lens, mounted on the equatorial mounting formerly owned by Mr. Burnham and kindly loaned by Professor Comstock.

A four and one-half-inch Brashear portrait lens, and a very short focus (1:1.9) Voigtlander lens of four inches aperture, were strapped to a fixed post and were used for quick exposures on the corona. Three Sonader lenses, kindly loaned by Mr. Ellerman, were placed on a small heliostat mounting and were given an exposure extending nearly through totality, with three different kinds of plates.

The plates with the small instrument have, in part, been developed. The results show an extension of the corona between three and four diameters of the moon. The corona, as shown on these plates, is singularly like that of January 1, 1889. There is a broad fish-tailed extension spreading out to the west more than half way to the planet Mercury, which shows on all the plates. A long, thick set, more or less pointed mass, extends to the east for several diameters of the moon. The poles are surmounted with fan-like systems of rays—the whole entirely characteristic of the sunspot minimum corona.

The results with the cœlostat show that it is by far the simplest and best instrument for securing photographs of the corona on a large scale. The results also show that the images could be made very much longer with much gain. An instrument of this kind for photographing the corona could safely be made several hundred feet in length with a corresponding increase of aperture.

G. A. Hill. A few remarks with regard to the observations especially made to determine the position of the moon. In several of the reports the idea is presented that the time predicted from the ephemeris was not accurate. This I think was caused by the position of the observer and his station not being exactly known. At Lawrenceville we had a transit telescope, and we computed the times of contact. The times of the second and third contact agreed within 0.5 second with the ephemeris, and the times of the first and last contact came within 1.9 second. The duration of the totality was exactly given from the ephemeris. At Barnesville we had a clock giving seconds, with the sixtieth second left out, and the gentleman who took the time there lost his count, omitting that second, so that we were a second late in our time. But this was not the fault of the ephemeris , but of the man who counted on the clock. I was much gratified with the condition of the sun on the morning of the eclipse. The sun was unusually steady, and we succeeded in obtaining contacts that were quite satisfactory.

M. B. Snyder. I would like to call attention to the prominence on the southwest corner of one of the plates. I observed it visually, and was puzzled by the peculiar extension of that prominence. There was a decided change in its character. At the top there was a gradual fading of the prominence and the corona; and this is brought out by the photographs shown.

Ormond Stone. In the observation of contacts it seems to me there is a different way from the usual way, and which is preferable to it. The method used by myself in the eclipse of 1878 was used by Mr. Morgan at the present eclipse, at my station. I am not aware that it has been used elsewhere. It gets rid of the difficulty which arises from the fact that, especially at the first contact, we recognize the contact by an indentation. In other words, we do not observe the first contact at all, but we recognize as the first contact a time which is not the first contact. The method which we used was this: A divided scale was placed in the field of the telescope, with twenty divisions on each side, with every fifth division a little longer. This was placed at the proper angle to correspond with the diurnal motion, and carefully focused. When the indentation in the sun's edge had the length of one division a record was made; when it had reached the length of two divisions another record was made and so on through. By examining the report of the eclipse of 1878 you will see how closely the different results agreed. The observations of the present eclipse have not been reduced, but it seems to me that some such method as I have described is far preferable to the method of noting the time when the indentation is large enough to be fairly visible.

Edgar Frisby. The observation of the first contact involves the knowledge of about the position where the contact will occur. Of course it is always a little late, but when the observer knows the position and is looking very closely, the error must be very small. We should expect the last contact to be very close; but I have found, from the experience of three of four observers, that the agreement was not so close as in the first contact. It seems after all to be more difficult to note the exact time of the last contact than of the first.

A Member. With reference to the remarks of Professor Upton, I may say that I had charge of the camera, attached to which was a visual telescope so that we should be able to know just when to get the flashes. The time of the first flash was successful, and I made the exposure and got a number of bright lines. The second exposure was made after about ten seconds, during the totality, and it partially showed the bright lines. The chromospheric rings were not well shown because we had no driving clock. The attempt to get the flash at the last contact was not successful in consequence of the shortening of the time of exposure. After this I made an exposure of ten seconds every minute, and several plates showed a continuous spectrum. One minute after the third contact the lines were beautifully shown. The cause of the apparent continuous spectrum was perhaps the fact that the background was not sufficiently bright to show dark lines. Possibly they were all there but not thoroughly brought out.

M. B. Snyder. You will remember that a year ago I called attention to the use of the phonograph as a means of recording the time. During this eclipse I have actually tried the phonograph, with results quite satisfactory. We concluded that we might observe the shadow bands, and erecting a screen directly opposite to the sun we observed these bands and recorded the results by the phonograph. In this I was assisted by Mr. Thompson.

Mr. Thompson. At Mr. Snyder's request I will say that having gone to observe the eclipse, I undertook in co-operation with him to watch for the shadow bands. I stood about twenty feet away, and about three minutes before the sun disappeared I noticed very faint streaks. I did not communicate this to Mr. Snyder until they became unmistakable. At that time they were moving, so far as could be determined, at about the rate of a man running, say, twenty or thirty feet per second or perhaps faster than that. The points were curved, and they appeared to be broken into little curves four or five inches apart. I should think the dark places increased in width as totality approached until the darkness seemed to cover the entire space, and a few seconds before the totality everything had gone into confusion, and there was no definite progress after that. Just after the totality I noticed that the same direction as before was maintained, but that there was another system of bands moving in the opposite direction. Thus there were two sets of bands moving in opposite directions, for a very short time, of which Mr. Snyder has the record in the phonograph. Those that moved in the original direction persisted, fading out gradually in about the same time they took to come on before totality. I think it very likely that the confusion which I noticed just before totality was due to the action of the two systems of bands.

Brown Ayres. As I have never figured in the scientific world as an astronomer, it may have been presumptuous for me to undertake to do so much as I did in the observation of the eclipse. But I realized that my position at New Orleans was near the center of the totality, and there were parties who came to our place to observe the eclipse, but who located on other grounds. The location seemed to be poor, and one or two who thought of coming gave it up. But I thought as we were the only institution of any magnitude on the line of the eclipse it would be absurd if we should allow it to pass without any observation whatever. When we received the little ephemeris sent out by the United States Naval Observatory, we laid our plans as to what we could do with the appliances at hand. The result was that I tried to observe the shadow bands, and to get the contacts as well as possible. That was my program until about ten days before the time of the eclipse; when Chancellor Fullerton of the University of Mississippi, wrote and offered to loan me a fine telescope of fifteen visual and nine-inch photographic aperature, made by Grubb. I received it gladly, and mounting it prepared to take some photographs with as much accuracy as I could. But the main point I had in view was to get the times of contact. There were different points in the city carefully determined and marked by the Coast Survey, so that I was able to get my position accurately, and I could get Washington time by signals in my observatory. I was able to make a very large number of comparisons to obtain the local time. The plan I adopted was a combination of visual and photographic work. We took the pictures as rapidly as we could feed the plates into the telescope, the position being carefully adjusted by star-trails, and we had a snap shutter automatically recording the time at which each picture was taken. This gave us a large number of photographs of which the time was accurately determined. We were so fortunate as to get a plate showing the Bailly beads, and the next plate was blank; so that we have secured a very accurate observation of the time of the second contact. At the time of the third contact I was peculiarly fortunate; for just as the plate was exposed by the snap shot, there was a sudden flash, and I think I have the time of that contact photographed pretty closely. In addition to my work, Professor Fullerton, who was within a few feet of my observatory, made visual observations; and I think we can work up some successful results. Instead of the collection of astronomers they had at Waynesborough, we enjoyed isolation, and the eclipse was an old story with us before they could do anything in Georgia or North Carolina. There was one little thing I should like to note, to which my attention was called by Mr. Brashear. It is that one large prominence which on my plates is distinctly turned over, half an hour later in Georgia was standing straight up. This shows the change which had taken place after my observations at New Orleans. We had beautiful weather until the eclipse was over, when it immediately clouded up. We took over fifty photographs; and although we had no astronomers with us, unless we count Professor Fullerton as one, I think we did our best.

Winslow Upton presented a report of shadow bands observed by John Ritchie Jr. of Boston, and also those observed by Edwin F. Sawyer.

W. J. Humphreys. Mr. Ayres states that just as the exposure closed, at the second contact, he looked up and saw the last of the sunlight go; that the totality had not quite begun when this exposure was made. The plates shows not only no dark line spectrum at all, but there were bright lines. This seems to show a very remarkable phenomenon. At the second and third contacts there was a slight depth of solar photosphere and a great deal of halation; but immediately after the third contact there is no halation whatever, and the lines are extremely bright, showing the crescent due to the plate and the chromosphere. I noticed something that seemed to be of the same character. It was two and one-half to three minutes before the second contact. I was observing with a telescope made up of a field glass and a small reflector, using no slit, and when I began observing I saw the narrow crescent of the sun as a dark crescent in the spectroscope. The form of the lines, instead of being straight, was crescent. Then the bright lines began to encroach upon the dark crescent, and the dark crescent began to shorten and broke up into a number of short crescents, and these came down to a narrow line, not a dark line but a bright line, which continued for nearly a second and then suddenly disappeared, when the whole field was filled with bright lines. The F line, at the time of totality, extended around almost the complete circle, perhaps three-quarters of the way round, and at that time there were only a few other lines observable. The magnesium lines showed somewhat. One thing I wish to call attention to is that the photograph shows that at the second exposure there were only bright lines and no dark lines at all. Mr. Gilbert was under the impression that the photosphere had not quite gone. The base of the chromosphere was intensely bright, and this is required for the reversal of the small lines which are produced very close to the photosphere. I also call attention to the fact that where the spectrum was almost continuous there was a very decided difference between the brightness of the bright lines and the dark lines. Very many of the dark lines were reversed, and there was no such phenomenon connected with the bright lines.

W. W. Campbell. This layer which is spoken of is shown in one photograph which was taken before the totality was ended, absolutely that and nothing else, and it extends over one hundred and fifty degrees on the western side of the sun. Another point that I wish to emphasize is our appreciation of the kindness of the Weather Bureau in sending us bulletins. The Weather Bureau observations showed that a strip of territory in western Georgia and in eastern Alabama, had the best chance of securing observations of the eclipse. But in fact I think we had the poorest weather. A minute after the eclipse was over the sun was thickly clouded over, a large mass of clouds coming up from the west. In connection with this I will say that a member of our party made it a part of his business to observe the corona, and he found that he could visually observe the corona seventy seconds after the eclipse was over. We thought it was not worth while to take photographs at that time, but we could probably have followed the corona longer except for the clouds which came up and covered the sky at that time. With regard to the green ring in 1898, which was shown very much broken up, indicating great coronal activity there, in this eclipse we had the green material piled up in large masses.

A Member. I was watching the region of F, to learn how to keep the image in the slit. It was not a gradual nor a sudden change, but a flickering one; and it went out a number of seconds after the totality in exactly the same manner that it came in, so far as its brightness was concerned. I am sure that if the best arrangements were made to economize the light, a grating of twenty-one and a half feet focal length could be successfully used. The light from that part of the sun which was upon the slit was not more than 1/200th part of that thrown by the cœlostat upon the ruled portion of the grating. If we could in some way economize the slit we might get good results from it.

Mr. Jewell. Probably the flickering spoken of was due to a slight tremulousness of the atmosphere. An interesting thing to observe was the carbon bands, which were exceedingly bright at a distance of one hundred or two hundred miles above the sun's surface, and which extended out about four hundred miles.

OBSERVATIONS OF EROS AT THE COMING OPPOSITION.

Simon Newcomb. Some one has divided astronomers into two classes, those who talk about things to be done, and those who go to work and do them. In the present case I am afraid we shall have to enroll ourselves in the first class, because it is not easy to do anything in this matter, the situation in this country not being favorable to the determination which we have in view. You are doubtless all aware of the great interest attaching to this remarkable asteroid. It may be said to supply us with what we have long been wanting, an object admitting of exact observation, which at proper intervals will come so near the earth that the solar parallax can be determined with greater precision than by any other method. It would hardly be possible to get one more exactly to fill the bill. The minimum distance of Eros from the earth is 0.15 of the distance of the earth from the sun. It follows, therefore, that at certain times it will be about as near to us as observations can advantageously be made. Were it to come very much nearer the additional advantage would be slight, for the reason that the elements of its orbit could hardly be known with sufficient accuracy to give us greater advantage; 0.15 is all that we can ask for, since that distance will diminish the effect of errors of observation by six or seven times. We have made very little progress in this direction for fifty years, and may now hope for something more. Yet in Eros, the Fates or whoever rules our destiny, have supplied us with something very tantalizing. It turns out that the nearest approach to Eros to the earth occurs only on rare occasions. A nearest approach occurred in 1894, and another approach as near as that will not occur until after the middle of the coming century. But an approach as near as can occur in the next twenty years will take place in the coming autumn, when its minimum distance from the earth will be about 0.3, or twice its absolutely shortest distance. It is very desirable that astronomers who devote their attention to the determination of the solar parallax, should take advantage of this opportunity for we shall have a parallactic displacement of Eros exceeding three times and possibly five times the solar parallax. But there are many drawbacks, the planet is faint; it will probably be, when nearest to us, but little above the ninth magnitude, and it will therefore be scarcely possible from its rapid motion to photograph it, or to ascertain its true position upon the plate at any given time. It is difficult to ascertain just how the observations upon it should be made. With the view of getting the ideas of those who are interested in the matter and of ascertaining how the stations can best be planned, I have published in the *Astronomical Journal* a paper upon this subject, accompanied by diagrams to aid in the selection of the observing stations. These diagrams give four projections showing the position of the earth as seen from the direction of Eros, at different periods during the opposition. (A copy of one of the diagrams was placed upon the blackboard). If we imagine an observer looking down upon the earth from Eros, the relative parallax between any two points upon the earth's surface, will be the distance of those two points as seen by the observer upon the planet. These diagrams therefore show us the advantages and disadvantages of any two stations we may choose. The line of sunset, showing when Eros will be visible to us, will be nearly the same for several nights in succession. Taking for example December 16th; in that part of the earth upon the left of the diagram, it will be day, and observers there cannot see the planet at all. It is only in the remaining region that an observer can see the planet. I will mark upon this portion degrees of latitude, showing the position of different observatories. On the circle of 60° north latitude, Pulkowa and Helsingfors are situated, their position upon the circle depending upon the time of observation. It is evident from the diagram that the parallax at those points will be very great; and those two places have the advantage of being near one end of the base line giving the greatest observable amount of parallax. The asteroid being so far north on December 16th, does not set at all at those places. It is evident that the best corresponding point, giving the longest base line, will be in the portion of the diagram south of the equator. The planet at that time is only visible about 15° south of the equator and the only observatory in that region is at Arequipa. If then observations are made at the Arequipa Observatory, for an hour or two, and if observations are also made at Pulkowa or Helsingfors for an hour or two, it will give us the longest possible base line for these observations. Observations may be made at other points, but they will be less available in the determination of the parallax than those made at Pulkowa or Helsingfors and at Arequipa. Another point for consideration is that if the two sets of observations are made at different times, the planet will be moving in the meanwhile. Its motion is very rapid, and an element of uncertainty is introduced by the necessity of determining the amount of this motion. If the observations at Pulkowa or at Helsingfors and at Arequipa are not simultaneous this uncertainty affects the result. The question arises therefore whether simultaneous observations can be obtained at the end of this base line. To determine that question we have only to imagine a map of the world upon this diagram. As the observer at Eros comes in sight of the oceans and continents of the earth, passing before him, he will see the two stations, at Helsingfors and at Arequipa; and observations cannot be simultaneous unless he can see both at once. We see that the conditions are extremely favorable. While Arequipa is passing along in *this* region, near the sunset line, Pulkowa will be passing along in *this* region, near the opposite horizon; so that we may combine observations made at Arequipa early in the evening, near the end of twilight, with those at Pulkowa several hours later in local time, in the latter part of the night, and they will be nearly if not quite simultaneous. We can thus obtain the maximum parallax, which will be 48″, with a little allowance for motion, from the observations of those two stations. Later in the season the Cape of Good Hope will appear above the horizon, and then another combination can be made, the circumstances will be less favorable. We might have observations at Paris, Greenwich, Potsdam, etc., but they will afford less favorable means of comparison than Pulkowa and Arequipa, which give the longest possible base line. As to our own position, we can observe in connection with Arequipa, but not easily; and in connection with the Cape of Good Hope, but when Eros rises with us it will set at the Cape of Good Hope. On the whole we cannot too strongly impress upon Professor Pickering the desirability of getting at Arequipa the best observations that can be made there, for combination with all the other stations. As to the method of making the observations, undoubtedly we must depend upon photography. There is no heliometer at Arequipa, and at the Cape it is not certain that it is available. It will not do to depend upon the heliometer. We must depend upon photography, and it is not easy for one not an expert to make valuable suggestions with regard to that. An additional complication arises from the rapid motion of the planet. It does not appear certain that the planet can be photographed at all so as to be available for this purpose. It must rest in one position long enough to take a picture or there will be no trace of it upon the plate. Professor Pickering says that there will be no difficulty in getting a trail; but that will not answer the purpose. In view of the fact that most of the stars will be brighter than the asteroid, photographs may be taken by focusing upon the planet and taking a trail of the brighter stars. But the difficulty remains of getting the time from the trails. Another difficulty is that we have no first-class photographic apparatus in the equatorial region, available for this purpose. I conclude that the combination of Pulkowa and Helsingfors with Arequipa ought to be our main reliance for obtaining the value of the solar parallax.

G. A. Peters. I should think that owing to the fact that the planet is upon the horizon during the observations for parallax, the light would be much diminished, and that the photographic plan would in that respect suffer a disadvantage in comparison with observations obtained visually. Unless large telescopes are used, and the atmosphere is extremely clear, there is danger that no observations can be obtained in that way.

Professor Newcomb. It is fortunate that at the stations where the planet is near the horizon the heavens are remarkably clear. At

Arequipa, Pulkowa and Helsingfors the vapors near the horizon are but a minute fraction of those in the clime of Washington. It is a curious meteorological fact that here the vapor is generally so dense that good seeing near the horizon is much more rare than at the stations selected.

C. G. Abbott. Would it not be well to use isochromatic plates?

Professor Newcomb. That is a detail that we shall probably have to leave to those who take the photographs.

S. J. Brown. I have given this matter some attention. It seems to me that micrometric observations could be carried on simultaneously, especially in the United States. We have Pulkowa, Strassburg, Charlottesville, Evanston, Madison, Princeton, Washington, and the Lick Observatory. and the Yerkes, where work can be advantageously done with large telescopes. While the factor of the parallax is very much smaller in the case of simultaneous micrometric observations, the main thing seems to be to secure the necessary co-operation, and to prepare a careful plan beforehand. The motion of Eros is so large that the observations will have to be very nearly simultaneous. The difference in the factor for parallax between Pulkowa and Washington is about 1.1. It is not much greater between Pulkowa and the Lick Observatory. It is 1.92 at Charlottesville; 1.26 for the Lick Observatory, 1.13 for Washington, and about the same for Princeton; so that by simultaneous observations between Pulkowa, Strassburg, Greenwich, and the observatories in the United States, we may obtain a parallax of about 15″ between the 1st of October, and January 16th. My impression is that stars should be selected not more than 60″ from the planet, and that they should be compared at nearly the same Greenwich mean time at all the stations. In this way observations may be obtained extremely valuable for determining the parallax. I am not certain but that the planet can be photographed to advantage: but it would require a long time, and the motion of the planet would be uncertain; so that the advantage I think would be out-weighed by the accuracy with which micrometric observations could be made; and if referred to the same stars, eliminating the motion of the planet, we might expect precision. The position of the planet can be ascertained closely enough, and its parallax known so nearly that we can measure it to advantage in telescopes varying from sixteen to forty inches in aperture in the United States. I had started to draw up a letter to be sent to the directors of the observatories of Pulkowa, Strassburg, and Greenwich in Europe, and in this country at Charlottesville, Princeton, Madison, the Yerkes and the Lick, asking that co-operative work might be carried on, and asking for a selection of the stars. If we assume 60″ for the greatest distance from the planet, and a parallax varying from 15″ to 30″, this will give a distance from 60″ to 90″; and you can go down to the 10th magnitude, the magnitude of the planet, and find in the field a number of suitable stars, which should be symmetrically situated in rectangular co-ordinates. In this way it seems to me that we can obtain from these large telescopes observations of as great accuracy as those obtained by the photograph, although the distance may be twice as great and the factor twice as great. I do not see that anything practical can be done by this association. It must remain for some one to take the initiative; and there ought to be no difficulty in getting suggestions to perfect such a simple plan, such as may result in saving the day for the observations of Eros. Photographic observations would have to be confined largely to Pulkowa, Berlin, or Potsdam, and Arequipa, the Cape of Good Hope will not come in until along towards the end of the opposition. It seems to me therefore that micrometric observation, under these circumstances will be a matter of considerable importance.

Professor Newcomb. We want these stars as nearly of the same magnitude as possible. In a space of 60′ square, the mean distance of the stars would be about 6′. The planet moves about 2″ of arc in a minute. An observer making a careful micrometric measure must take at least ten or twenty seconds to make up his mind about the bisection. During ten seconds the planet will have moved over a space of 1/3″ of arc, a quantity not appreciable but still large enough to leave open the question whereabouts during that period of ten or twenty seconds occupied in making the bisection, the planet actually was at the time assumed for the bisection. There arises an uncertainty which may be systematic. It may be different for different observers and different places. This uncertainty seems to preclude dependence upon the process of micrometric measurement. In the case of the satellites of Saturn we know that results are obtained differing enormously.

S. J. Brown. And for the satellite of Neptune the difference is still greater.

Professor Newcomb. There are some systematic differences attending micrometric observations, but these can be diminished if we take our observations to avoid them. We have the method of difference of right ascension and declination, when we take the right ascension entirely free from the declination, taking the right ascension at the time of passing a certain thread. If the star is chosen of about the same magnitude as the planet, it will be free from one source of systematic error, but there may be a great many others. If each set requires a minute or two, and if two threads are used, you may make sixty comparisons in an hour, which I think will be more than can be done with the micrometer. There is then much room for systematic error.

G. W. Hough. I think the most accurate work can be done with the micrometer. With an 18½-inch telescope there is no trouble in seeing an eleventh or twelfth magnitude star; and it is only necessary to get the time of the bisection and the position angle and distance. The time can be known within a few seconds, and ten observations can be made as readily as one. So we can get a final result free from systematic error.

Simon Newcomb. That may be quite possible for a twelfth magnitude star.

G. W. Hough. The method of differences of right ascension and declination I use very often; but then we must depend upon the stability of the telescope. It may require one and one-half to two minutes to pass from the star to the planet, and there is a liability to error from the action of the wind or from other causes. In photographic work the star will be near the horizon at the time required for its observation, and the time required will be very long, especially if we use isochromatic or other such plates; and that will be a great objection.

W. W. Campbell. It seems to me that both the methods suggested should be submitted to actual trial before the entire campaign is based upon either method. It ought to be possible by means of known asteroids moving rapidly to obtain photographs, by allowing the stars to trail or the asteroid to trail, and we could learn with what accuracy the position of the asteroid can be obtained upon a certain plate. Furthermore it will be easy to test the method of observing faint stars near the asteroid. In large telescopes it will be possible either to get a star of the twelfth or thirteenth magnitude within one minute of arc, and by selecting stars in different directions from the asteroid it will be possible to eliminate practically all the personal element entering into the question. In my experience in micrometric measures there is never an uncertainty greater than two or three seconds as to the exact instant of bisection, and the motion of the planet in that time, for that particular observation, will be small as compared with the accidental error probably made. If we take ten observations together the motion of the planet will be practically unimportant. My main point is that the method fixed upon should be actually submitted to test before the campaign is started. It would be a serious matter if the campaign should be carried on, and afterwards it should be ascertained that in consequence of some oversight the results are of very little importance.

G. C. Comstock. If twelfth magnitude stars are to be used in the comparisons, can provision be made to secure the observation of the same stars at the different stations?

W. W. Campbell. A photographic plate can be secured from which the accurate positions of these stars can be ascertained.

G. C. Comstock. Is there time for this before the campaign begins?

W. W. Campbell. I think there should be a carefully prepared plan.

S. J. Brown. In relation to the observation of differences of right ascension and declination, all the observations will have to be made before we can determine the corrections, because the changes of right ascension and declination will not be in proportion to the elapsed time in consequence of the rapid motion of the asteroid. We need to eliminate the systematic errors. You mark your time, and your measurement does not correspond with the time you have marked. That leads to a systematic error. If we can eliminate this I think that observations of great accuracy can be made. In this case it is proposed to select stars which shall not be more than thirty seconds in time away from the planet. In micrometric measures the suggestion is 60″, which added to the displacement of the planet amounts to 90″. Above that distance there would be a rapid increase of probable errors. The main difficulty appears to be in the selection of stars down to the eleventh or twelfth magnitude.

W. W. Campbell. It seems to me that the method of observation by transits is objectionable. With the equatorial telescope there is a tremendous personal equation in the observation of stars and comets. Undoubtedly there will be a similar personal equation in the observation by transits of an asteroid and a faint comparison star differing three or four magnitudes from the asteroid. There are many things that may occur; the refraction may be changed, or the position of the instrument may be changed if we wait a minute or two for the comparison star to come along. Our experience in the observation of comets shows that very much better observations can be secured if we throw overboard the method of observing differences of right ascension and declination.

G. W. Hough. I disagree as to the time required for the observations, and I have made thousands of observations of differences of right ascension and declination. But one measure of the position angle is better than anything you can get from differences of right ascension and declination.

S. J. Brown. We have to shift the micrometer 90° in taking the position angle. Suppose the planet to move 1″ per minute, the change in the angle is not proportional to the time, and the change in the distance is not proportional to the time. I have come to the conclusion that differences of right ascension and declination can be determined with greater accuracy than differences of position angle and distance. One point we wish to agree upon is a uniform method of measurement. Observations cannot well be compared if one observation is made upon one plan and another observation upon a different plan. I have no doubt that the difference in magnitude is a very important factor in determining the position. In my observations of Titan I reduced my observations by the method of least squares, and all the equations gave positive residuals except one; and that could only be explained upon the theory of variable personal equation from difference of magnitude. Even with faint stars it would be difficult to use differences of right ascension observed with the chronograph or eye and ear. I think we ought to have the experience of those who have had experience with stars of the magnitude to be used as to their method of treating them. The photographic method I think is subject to special dangers on account of the low altitude of the asteroid in the southern hemisphere.

W. W. Campbell. The base line which Professor Newcomb has indicated has a great extent, but as to successful working much depends upon wise compromise which ought to be considered. At the expense of longer observation the observers are going to work near the horizon, where the refraction will be more uncertain. Furthermore the image to be measured will not in all cases be satisfactory on account of the vapors rising near the horizon. What amount of difference in the base line will outweigh the differences in the atmosphere we shall have to compete with? It appears to me that a base line which gives only two-thirds of the parallax may be more accurate than one which gives five-sixths, in consequence of the better conditions under which the observations may be made.

G. C. Comstock. We should not be mislead by the drawing upon the blackboard, because it is not drawn to scale. Taking the indicated positions, we shall not bring our observations very near the horizon. I agree that we should not seek the maximum possible base line, there are other considerations in the problem, but we should get the longest base line we can without encroaching upon the horizon, and Pulkowa and Arequipa do not crowd the observations upon the horizon.

S. J. Brown. We have to take the telescopes as they can be found. At Pulkowa they have an excellent telescope, and at Arequipa also; and they are of identical power. These two stations are fixed, therefore, by the facts of the case. And so the Cape of Good Hope will be fixed as another station. The photographic program is fixed. I think the matter will be settled according to the circumstances as they exist now. We have three photographic telescopes of thirteen-inch aperture distributed very favorably in the southern hemisphere, and three or four in the northern hemisphere. The micrometric problem is one which I think the astronomers of America can agree to co-operate in, and I think we ought to have considerable influence in inducing Strassburg and Greenwich to co-operate with us. If we can secure the agreement of astronomers in this country and send word to those in Europe before October 1st, we may possibly save the situation, and perhaps produce results comparable in accuracy with those from the photographic plates. The planet may be observed at Pulkowa and Washington from October 1st to January 16th, the observations at Pulkowa extending to an hour angle of six or seven hours. Then the planet would have an altitude of 30° ; and the factor can be extended from 15″ to 30″ or even 35″. But I have been unwilling to write to foreigners until I could ascertain the opinions of astronomers here.

Winslow Upton. I think if Professor Pickering were here he would assure us that Arequipa is remarkably well situated to adapt it for a southern station. The condition of the climate and the atmosphere is favorable, and it has an elevation of 8000 feet above the level of the sea, ensuring good definition. Again, the twilight there is always short. We can be perfectly sure that Professor Pickering will use the facilities of the situation to the utmost. But there is a difficulty from the unknown law of refraction. The discussion of the observations will take the differential form, but the law is not known at all. These considerations do not apply to Pulkowa, but there the planet will not be low.

F. L. Chase. With regard to diurnal motion, will it be possible to eliminate the motion of the planet?

S. J. Brown. I think the micrometric method in that respect out of the question. The motion of the planet is about 10′ in ten hours, and it would be difficult in a large telescope to measure that arc of 10′. We find that with the great telescope at Washington we are limited to 4′ or 5′. Beyond that we do not get good results. You cannot make the observations without shifting the eyepiece; and I have made up my mind that for the purposes of micrometric observation the diurnal plan would be out of the question.

J. G. Hagen. Referring to the photographic method, there is a difficulty which has not been discussed. The motion of the planet, in taking a photograph, which may require an hour or more, will produce a trail. There is an opportunity to choose between allowing the planet to trail, and allowing the stars to trail. Perhaps the same object, of securing an accurate position for the planet upon the plate, can be attained by interruption of the exposure. The time of the motion can be known within ten seconds; and while the planet, of the ninth magnitude, may be obtained upon the plate, the bright stars may be obtained in a series of dots, each exposure giving an independent determination. Whether these interruptions should be made once in ten seconds or once in a minute is a question for experiment. I merely make the suggestion of a method that may remove the difficulty.

S. P. LANGLEY

THIRD MEETING

The first winter meeting of the Astronomical Society was held at the Cosmos Club, Washington, D. C., on Monday, Tuesday and Wednesday, December 30, 1901, to January 1, 1902. Sessions for the reading of papers were held both morning and afternoon on Monday and Tuesday and on Wednesday morning. The maximum attendance of about fifty was reached on Tuesday.

A number of members lunched together at Barton's on Monday and Tuesday, and on Monday evening attended a dinner at the same place. The president of the Society presided, and among the delightful features were the after-dinner speeches by Professors W. W. Campbell, George E. Hale and Solon I. Bailey.

On Tuesday evening President and Mrs. Newcomb received the members of the Society and numerous guests at a conversazione held at the Arlington Hotel. During the evening papers illustrated with lantern slides were read by Professor Percival Lowell on Mars, by Professor S. P. Langley on personal equation and on the infra-red spectrum, by Professor George E. Hale on a comparison of the results obtained by photography with the forty-inch refractor and the twenty-four-inch reflector at the Yerkes Observatory, and by Professor W. W. Campbell on the work of the Lick Observatory eclipse party in Sumatra and on the nebula surrounding Nova Persei. At the conclusion of the reading of these papers, all adjourned to an adjoining room, where numerous astronomical photographs and transparencies were being exhibited. These included some of the most notable achievements in this direction from the Harvard College Observatory, the Lick Observatory, the Yerkes Observatory, and the United States Naval Observatory.

On Tuesday a number of the members visited the Astrophysical Observatory of the Smithsonian Institution upon a special invitation to the Society by Secretary Langley.

At the adjournment of the session on Wednesday morning, the members visited the White House and paid their respects to President Roosevelt, special arrangements having been made for their reception.

The election was held on Wednesday, resulting in the selection of officers for the ensuing year as follows:

President	Simon Newcomb
First Vice-President	George E. Hale
Second Vice-President	W. W. Campbell
Secretary	George C. Comstock
Treasurer	C. L. Doolittle
Councilors	Ormond Stone S. J. Brown E. C. Pickering R. S. Woodward

Professor W. S. Eichelberger was appointed Editor for the meeting.

RESOLUTIONS ADOPTED

Resolved, That the members of the Astronomical and Astrophysican Society in attendance at this meeting hereby tender their cordial thanks to the Board of Management of and to the members of the Cosmos Club for the use of the Club, Assembly and Council rooms, for the excellent facilities afforded for the illustration and exposition of the papers presented at this meeting, and for the kindly social courtesies extended to all members of our Society.

Resolved, That the thanks of this Society be tendered to Professor S. P. Langley for the special opportunity afforded by him to visit the Astrophysical Observatory of the Smithsonian Institution.

Resolved, That the thanks of the Astronomical and Astrophysical Society be tendered to the Philosophical Society and to its treasurer, Mr. Bernard R. Green, for the use of apparatus and courtesies shown during the present meeting of the Astronomical and Astrophysical Society.

Resolved, That the Secretary of the Society be requested to transmit the substance of these resolutions to the Board of Management of the Cosmos Club, to Professor S. P. Langley and to the officers of the Philosophical Society respectively.

Resolved. That the members of the Society in attendance hereby express their cordial appreciation of the active services of the President in perfecting all arrangements for this meeting and in providing so amply for social as well as for astronomical and astrophysical entertainment.

ABSTRACTS OF PAPERS

THE FLASH SPECTRUM, SUMATRA ECLIPSE, MAY 18, 1901.

BY S. A. MITCHELL.

The writer, through the courtesy of the director of the Naval Observatory, became a member of the expedition to view the Sumatra eclipse on May 18, 1901, and was stationed at Sawah Loento. Two instruments were employed, a camera of 104 inches focus to be used in connection with a cœlostat; and a spectroscope consisting of a Rowland flat grating of 15,000 lines having a ruled space of 3½ x 5 inches, and a quartz lens of 3-23/64 inches aperture and 72 inches focal length. Light from the sun reflected by the cœlostat mirror in a horizontal direction, fell on the grating where it was diffracted, and was brought to a focus on the photographic plate by means of the quartz lens. If grating and photographic plate are each perpendicular to the diffracted beam, the spectrum is 'normal.' It was arranged to photograph the first order spectrum from λ 3000 to λ 6000.

The weather on the day of the eclipse was extremely disappointing. First contact was observed in a perfectly clear sky, but clouds soon began to gather and were so dense at second contact that the first flash was not observed at all. Toward the middle of totality conditions became a trifle better, so that it was possible to see, through clouds, the corona extending for about half a diameter from the sun. During no time of the 5 min. 41 sec. of totality was an unclouded view of the corona obtained, but nevertheless, the second flash was seen beautifully. Altogether eight exposures were made, one before and one just after totality for the cusp spectrum, one at first and one at second flash and four with different lengths of exposure during the total phase. The second flash seemed fully exposed, and it is to a discussion of this photograph that this paper is devoted.

The peculiarities of this photograph are:

(1) Normal spectrum, and (2) Great dispersion.

On the plate the distance from F to H is 95.4 mm., and as the spectrum is normal, 1 mm., therefore, corresponds to a difference of wave-length of 9.37 tenth-meters, or 1 tenth-meter corresponds to a dispersion of about 0.1 mm. For some reason, the spectra were not in perfect focus, but in spite of this fact, in view of the great dispersion of the spectrum, measures were made and wave-lengths determined with a high degree of accuracy. The spectrum extends from λ 4924 to λ 3320, but the focus becomes poor beyond K, and measures were discontinued at λ 3835. For the purposes of the present comparison, the region from F to H only was regarded. In this part of the spectrum three hundred and sixty-three lines were measured in the flash. An arbitrary scale of intensities was assumed whereby 0 represents the faintest line seen with certainty, 10 the strongest line. Wave-lengths were compared with Rowland's measures of the solar spectrum. Of the three hundred and sixty-three flash lines, two hundred and sixty-nine were identified with lines on Rowland's map. Although we cannot directly compare the intensities of the bright lines of the flash (scale 0-10), with those of the dark lines given in Rowland's tables (scale 1-1,000), we can arrive at certain theoretical considerations if we compare the average intensities for the different elements, *i. e.*,

$$\frac{\text{Flash intensities}}{\text{Solar intensities}}$$

and also the ratios of the number of lines of each element identified to the whole number of solar lines for that metal. Forming these ratios and arranging them, we are at once struck with the systematic variations, not only in the ratio of intensities, but also in the per cent. of lines identified. The meaning of these systematic differences will be understood if we consider these ratios in combination with the atomic weights of the various elements, as in the following table, where also is put down the number of the lines in the flash due to each metal.

GROUP I.—LINES STRONG IN FLASH AND IN SOLAR SPECTRUM.

Element.	Atomic Weight.	Number of Lines.	Intensity Flash. / Intensity Solar Lines.	Lines Identified. / Total Number of Lines.
Na	23.0			
Mg	24.3	1	0.10	1.00
Al	27.1			
Ca	40.0	8	0.34	0.38

GROUP II.—LINES STRONG IN FLASH, WEAK IN SOLAR SPECTRUM.

Element.	Atomic Weight.	Number of Lines.	Intensity Flash. / Intensity Solar Lines.	Lines Identified. / Total Number of Lines.
Sc	44.1	6	0.86	0.75
Ti	48.1	62	0.67	0.70
V	51.2	15	0.49	0.68
Cr	52.1	38	0.56	0.64
Mn	55.1	27	0.25	0.48
Sr	87.6	2	1.08	0.67
Y	88.7	2	0.50	0.67
Zr	90.6	8	0.27	0.62

GROUP III.—LINES WEAK IN FLASH, STRONG IN SOLAR SPECTRUM.

Element.	Atomic Weight.	Number of Lines.	Intensity Flash.	Lines Identified.
			Intensity Solar Lines.	Total Number of Lines.
Fe	56.0	125	0.23	0.32
Ni	58.7	9	0.32	0.28
Co	59.0	6	0.19	0.29

These lines naturally fall into three groups, as given in the above table.

To these may be also be added the following lines:

La, atomic weight, 138.5 ....3 lines
Ba, " " 137 ....1 line
Ln, " " 65 ....1 line

In Group I would also fall Al if we consider the relative intensities of the two lines λ 3944.160 and λ 3961.674; and undoubtedly Na if our plate took in the D lines. The remarkable variation of the relative intensities in the flash and Fraunhofer spectra, as Evershed has pointed out, is undoubtedly due to the *heights* to which the vapors of the different metals ascend in the chromosphere. A gas with an intrinsic brightness 1 and a layer one hundred miles in thickness, would give a photographic line in the flash spectrum just as bright as a gas of intrinsic brightness 100 and only 1 mile thick, if the sun and moon were relatively at rest during the period of the flash; but considering the gradual advance of the moon in covering successive layers of the sun's atmosphere, we see that in the emission spectrum the flash line of the fainter gas would be many times more intense than that of the brighter. The absorption lines of the two gases would be very nearly the same. The extent of the metallic vapors of the sun's surface probably varies inversely proportional to their atomic weights.

In consideration of these facts, it seems altogether likely that the gases of the metals of Group II extend very high, and are nowhere very much condensed. The flash lines are to be regarded as true reversals of the corresponding solar lines. The metals of Groups I and III are somewhat denser near the sun's surface and do not extend so high as those of Group II, but as it is the upper portions that contribute most to the formation of the emission lines, the flash lines are to be regarded as only partial reversals of the Fraunhofer lines, the solar intensities being greater than the flash intensities. Most of the strongest lines in the solar spectrum have been found in the flash; and this, taken in connection with the meaning of the differences of intensities, leads us further to renew our faith in the existence of the 'reversing layer.'

THE TOTAL SOLAR ECLIPSE OF MAY 18, 1901.

BY C. D. PERRINE.

The expenses of an expedition to Padang, Sumatra, from the Lick Observatory, to secure observations of this eclipse, were defrayed by Mr. William H. Crocker, of San Francisco. Eclipse day dawned with light clouds covering the sky. But little change occurred during the morning. At the time of first contact, the sun shone through a rift in the clouds. At the beginning of totality all parts of the sky near the sun were covered with light cirrus clouds and haze. The inner corona only and Mercury and Venus could be seen during the early part of totality. The clouds became very much heavier towards the end of totality. The time of beginning and ending of totality was three or four seconds later than the time of these phases computed from data given in the *American Ephemeris,* but the uncertainty of longitudes in Sumatra may account for nearly if not all of this. Twelve photographs of varying exposures were secured with a camera of forty feet focal length. These show the inner corona and prominences as well, probably, as if the sky had been free from clouds. The longest exposure, one of 150 seconds, shows the streamers to a distance of one and one-third diameters from the limb—more than could be seen with the unaided eye. A number of small prominences are visible on the east limb of the sun. One of these at position-angle 115° is covered with a series of coronal hoods or envelopes. Attention is called to a remarkable disturbance in the corona in the northeast quadrant. At a position-angle of about 65° there is a small compact prominence, over which there is a disturbed area resembling roughly an inverted cone. From the apparent apex of this area a number of irregular streamers and masses of matter radiate as if thrown out by an explosion. I am not aware that a disturbance of this kind has been observed before in the corona proper. Eight photographs were secured with the Floyd telescope of seventy inches focal length. These negatives show the same extensions of corona as those taken with the forty-foot camera. Twelve negatives were secured of six regions on either side of the sun in the direction of his equator for the purpose of detecting any planets existing there. These negatives were obtained with lenses of three inches aperture and 11 feet 4 inches focal length.* A preliminary examination of these negatives was made at the station and 92 stars of magnitude 8.6 to 8.8 were found in three of the regions. The plates taken during the latter part of totality show no star images, owing to the increased cloudiness. A negative with long exposure was secured with each of two spectrographs, one having the slit tangential, the other radial. The principal Fraunhofer lines are shown in the outer corona in both, none, however, being observable in the extreme inner corona. Ten negatives were secured with a camera of twenty-one inches focal length, having a double-image prism placed in front of the objective. The two images given by such a prism and camera furnish a means of detecting by differential methods any considerable polarization in the corona. The axis of the prism was set at several different position angles between the sun's equator and his poles. In this way all parts of the corona were tested. The negatives secured show a large percentage of polarization in the outer corona and a slight amount in the inner corona. The two spectrographs and the polarigraph were designed and prepared for use by Director Campbell and Assistant Astronomer W. H. Wright.

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*Two of the four lenses used in Sumatra were kindly loaned for the purpose by Professor E. C. Pickering, Director of the Harvard College Observatory.

The great southern comet was a conspicuous object in the evening sky for several days and was visible without aid for more than a week. Photographs of it with a portrait lens were secured on May 6. The exposures were necessarily short, but show 3° or 4° tail. A faint streamer is also shown to the south, making an angle of about 35° with the principal tail. A number of large copies, on glass, of the eclipse photographs, as well as lantern slides, were shown at the meeting.

A MARTIAN CLOUD.

BY PERCIVAL LOWELL.

This paper gave an account of two projections seen upon the terminator of Mars by Mr. A. E. Douglass at the Lowell Observatory on December 7 and 8, 1900; the observations which gave rise to the popular impression last year of signals from Mars. Calculation showed them to belong to different parts of the planet and to have moved during the time they were under observation. Furthermore, the motion in each case was approximately the same—nearly due west in each case. Neither of them reappeared on any succeeding night. They thus showed themselves to be not illuminated mountain tops, but sunset clouds floating in the planet's atmosphere.

PRELIMINARY STATEMENT OF RESULTS OF INTERNATIONAL MAGNETIC OBSERVATIONS MADE DURING THE TOTAL SOLAR ECLIPSE OF MAY 17-18, 1901.

BY L. A. BAUER.

To test further the results obtained by the United States Coast and Geodetic Survey magnetic parties during the total solar eclipse of May 28, 1900, regarding a slight magnetic effect that may be attributable directly to some change produced in the electrification of the upper atmospheric strata by the abstraction of the sun's rays, due to the interposition of the moon between the sun and the earth, an appeal was made for international co-operation in magnetic and allied observations during the recent total eclipse. The repetition of the observations was doubly interesting owing to the fact that the present eclipse occurred in the opposite magnetic hemisphere to that of last year, and hence the opportunity was afforded for ascertaining whether the magnetic effect was reversed in its general character to that of last year as is, for example, the case with the diurnal variation in passing from one magnetic hemisphere to the other. The conditions, however, for obtaining observations at a number of stations distributed along the belt of totality, as was done last year, and thus testing whether the magnetic effect again followed directly in the wake of the shadow cone, were not favorable owing to the present location of the belt of totality. In response to the appeal, simultaneous magnetic observations were made on May 17 from 14 to 21 o'clock, Greenwich mean astronomical time—an interval amply covering the time of the eclipse—at a number of stations encircling the entire globe, three of which were in the belt of totality. The prime purpose of making the observations so as to cover the entire globe was to furnish the possibility of separating a possible eclipse magnetic effect from a contemporaneous magnetic storm of the usual type. The eclipse effect, for instance, doubtless would be confined to a very small belt, whereas a customary magnetic storm, in conformity with the usual experience, would manifest itself at practically the same moment of time over a very large area, and thus be felt at stations far from the totality belt. At none of the outside stations has a disturbance of any appreciable size been thus far reported to me, the general consensus of opinion of observers at these stations being that 'nothing unusual occurred.' At the three stations within the belt of totality the majority of the opinions is that something unusual did occur during the time of the eclipse. Thus at

Karang Sago, where was situated the Dutch eclipse party, Dr. W. van Bermelen, assistant director of the Batavia Magnetic Observatory, observed the change in the magnetic declination and horizontal intensity, and he reports the occurrence of 'an extremely interesting magnetic effect.' He has courteously sent me an extract of his observations made during several days before and on the day of the eclipse, and there certainly appears evidence of a magnetic effect in both elements different from that observed on the days prior to the eclipse. At Sawah Loento, the site of the Massachusetts Institute of Technology party, of Boston, the variations in magnetic declination were observed by Mr. G. L. Hosmer on May 17 and 18. Comparing the two days' results for the interval of the eclipse, there is indisputable proof that something different occurred on the day of the eclipse than on the day before. Namely, at this station, situated so close to the magnetic equator the range of the diurnal variation of the magnetic declination is about one minute of arc. The magnetic effect during the time of the eclipse was of about the same amount, so that a steady *decrease* of east declination resulted during the time of day when normally there is a steady *increase*. There was but one magnetic observatory directly within the belt, viz., the one at Mauritius and this was situated not far from the place of beginning of the eclipse. No special magnetic observations were made at this place; however, the regular photographic curves giving the variations in the magnetic elements were obtained. The declination and the vertical intensity curves apparently do not show any disturbance that could easily be picked out and referred to the eclipse. Regarding the horizontal intensity curve—the more sensitive one—Mr. Claxton states 'that the original curve shows slight tremors between 7.15 and 7.50 and occasionally between 8.5 and 9.0 a. m.' I have plotted this intensity curve on a large scale and find that the curve shows no very marked disturbance that might be readily referred to the eclipse, with the exception of one producing an easily perceptible bulge in the curve amounting to about 3-4 units in the fifth decimal c.g.s. units and lasting about thirty minutes. Anyway the effect, if there be one, is very minute, and will not be so readily separated from the usual diurnal variation as in the case of the two previous stations. Whether this is due to the fact that owing to the vicinity of Mauritius to the beginning of the eclipse, the minute eclipse magnetic storm did not have time to develop itself or was just in the embryonic state, cannot be said. The magnetic effect observed at Karang Sago and at Sawah Loento does not appear to have extended very far outside of the belt of totality, it being scarcely appreciable at the Batavia Magnetic Observatory. My grateful and appreciative acknowledgments are due to all who have participated in this interesting investigation—one to my mind of fundamental importance to the theory of the diurnal variation of the earth's magnetism as elaborated by Schuster and von Bezold.

MERIDIAN CIRCLE POSITIONS OF NOVA PERSEI.

BY R. H. TUCKER.

Meridian circle positions were obtained on eight evenings in February and March, and on four evenings in November. The difference in the right ascensions resulting from the two series of observations is 0.05 seconds. The star was more than four magnitudes brighter at the time of the first series than at the second. Making allowance for the magnitude equation, the difference between the right ascensions for the two series reduces to 0.01 seconds. The declinations in the two series differ by 0.05″. It is therefore evident that these observations indicate a very small parallax and proper motion. The large proper motion recently reported by a European astronomer is not confirmed.

ON THE PARALLAX OF NOVA PERSEI.

BY F. L. CHASE.

This paper was based upon observations made with the Yale heliometer, the first set in February and March, the second in July and August and a third in December. The result derived for the parallax confirmed the value found from the first two sets alone, in which the proper motion could not be taken into account, which value was published in a paper presented at the Denver meeting of the American Association for the Advancement of Science last August. This value was practically zero relative to the mean parallax of the two comparison stars employed, stars of about the eighth magnitude. In conclusion the author remarked that, considering its probable error, the value found was not incompatible with that required by the hypothesis advanced by Wolf and others, viz., that the apparent displacements in the nebula surrounding the Nova represent a velocity corresponding with that of an electric wave.

NOTE ON THE PARALLAX OF NOVA PERSEI.

BY R. G. AITKEN.

An attempt was made to determine the parallax of Nova Persei from the micrometric measures of six faint stars near it. The first set of measures was obtained, under very unfavorable conditions, shortly after the appearance of the Nova, and a second set on two nights in the latter part of July. The resulting values of the relative parallax were all negative, so that no conclusion can be drawn, unless, possibly, that the parallax of Nova Persei is very small. No account was or could be taken of possible proper motion.

THE ENERGY OF CONDENSATION OF STELLAR BODIES.

BY R. S. WOODWARD.

This paper considers the density, pressure and energy of condensation from a state of infinite diffusion, of a spherical stellar body in which Laplace's law of density holds. Denoting the potential, density, and pressure at a distance r from the center of such a mass by V, ρ and p, respectively, the problem is stated in three equations, namely:

$$\frac{\delta^2(rV)}{\delta r^2} + 4\pi k r\rho = 0,$$

$$dp = c\rho d\rho = \rho dV,$$

wherein k is the gravitation constant and c is the constant connecting density and pressure in Laplace's celebrated hypothesis. Assuming the density to vanish at a distance r from the center of such a body, it turns out that V, ρ and p are given by the following formulas, in which ρ_c and p_c are the central density and pressure, respectively, and M is the mass of the star:

$$a = \pi/r_0, \qquad q = \sin ar/(ar),$$

$$\rho_c = M\pi/(4r_0^3), \qquad p_c = M^2k\pi/(8r_0^4),$$

$$V = \frac{Mk}{r_0}(1 + q), \qquad \rho = \rho_c q, \qquad p = p_c q^2.$$

The energy of condensation of such a mass is found to be

$$\tfrac{3}{4}\frac{m^2k}{r_0} = \tfrac{3}{4} Fr_0,$$

where F is the force of attraction between M and an equal mass of infinitesimal volume situated at a distance r_0 from the center of M. It will be observed that the results here given require no hypothesis as to the temperature of such bodies.

OPTICAL DISTORTION OF PHOTOGRAPHIC TELESCOPES.

BY HAROLD JACOBY.

The observations discussed in the present paper form part of a more extended series undertaken in the year 1895, having for its principal object a study of the optical distortion of astronomical photographic objectives. A question had been raised as to the fidelity with which photographic telescopes reproduce upon the negative exact relative positions of the stars as they appear on the sky. This matter is fundamental to the art of astronomical photography throughout the entire range of its more important applications to stellar parallax, interstellar motion within the close clusters, and star charting in general; so that the large amount of labor involved even in its partial elucidation does not appear to be superfluous. Valuable co-operation in the work has been granted with ready kindness by several astronomers; and with their aid the special problem under investigation has been solved in a fairly satisfactory manner.

This special problem may be thus stated: Is the scale-value of an astronomical photograph absolutely independent of the direction of measurement on the negative? In other words, if we determine the co-ordinates of star-images on the plate in millimeters with reference to a pair of rectangular axes, the question is: Will a distance of one millimeter measured from the center of the plate along the X-axis correspond to precisely the same number of seconds of arc on the sky as a distance of one millimeter measured from the same center along the Y-axis? The matter may be put in still another way. Suppose there were upon the sky a number of stars so situated as to form a small but perfectly exact circle. Would a photograph show these stars situated upon a similar exact circle on the negative, or would defects of the object glass distort their position into an ellipse-like oval, after the manner of atmospheric refraction? If this is the case, equal diameters of the circle on the sky will become unequal diameters of the oval on the plate; and, in general, equal distances upon the sky expressed in seconds of arc will become unequal distances upon the plate expressed in millimeters, even after correction for all known sources of difference, such as refraction, aberration, etc.

Various investigations of optical distortion have been published by Donner, Turner and others; but they were all made by methods necessitating a knowledge of relative star positions based on measures other than photographic. To avoid this inherent difficulty, the writer suggested in 1893 a process in which it is not essential to have a precise previous knowledge of relative star positions. It is thus rendered entirely unnecessary either to make a laborious and time-consuming heliometer triangulation, or resort to comparatively inaccurate star-places, such as those obtained with meridian instruments. Proper motion, also, which necessitates new heliometric triangulations made very near the date of the photographic observations, is altogether eliminated in the use of this method.

It is merely necessary to arrange the telescope so that it can be rotated around its optical axis, or some other axis, parallel to its optical axis. Suppose two photographs of a group of stars have been made with such a telescope, rotated 90° between the two exposures. If, then, the object glass possesses the peculiarity of making all the Y-coordinates too large in the first exposure, the same peculiarity will show itself in the second exposure by making all the X-coordinates correspondingly too large. Thus it is sufficient to make a series of negatives of the same star-group, rotating the instrument through various angles between the exposures, when a simple comparison will surely bring to light any form of optical distortion depending on the direction of measurement upon the plate.

The process is a purely differential one, and requires only a roughly approximate knowledge of the absolute star-positions, sufficient for the computation of refraction corrections, etc. It can be applied to an equatorial telescope of the ordinary form if we photograph the region immediately surrounding the pole of the heavens. In that case, the polar axis of the equatorial becomes a suitable axis for rotating the telescope, since the polar axis is parallel to the optical axis, when the tube is pointed at the pole. It is obvious that a trial of this method will furnish not only a determination of optical distortion but will yield also, as a sort of by-product, a photographic catalogue of the close polar stars. For this reason it seemed desirable to include in the work a set of plates of the south pole as well as the north. In this way we should obtain very precise catalogues of both sets of close polar stars, all reduced and computed according to a uniform method.

In 1895 the writer was visiting at the Cape of Good Hope Observatory, and discussed the matter with Sir David Gill. The plan met with his approval, and he consented gladly to make the necessary south polar plates. With equal readiness, Dr. Anders Donner, of the Helsingfors Observatory, offered to make the north polar plates. These latter negatives were measured at Columbia University by Mrs. Herman S. Davis and Mrs. Annie Maclear Jacoby; the measures were reduced at Vassar College by Miss C. E. Furness; and they were published by the Vassar College Observatory. The south polar plates were similarly measured and reduced at Columbia by Misses F. E. Harpham, Mary Tarbox, Eudora Magill and H. L. Davis, and the results will soon be published by the Observatory of Columbia University. The researches for both poles agree in showing that the optical distortion depending on direction of measurement is too small to be detected with certainty even by the delicate differential method here described.

THE CONSTANT OF ABERRATION.

BY C. L. DOOLITTLE.

For some time a revision of the latitude work carried on at the Sayre Observatory, Bethlehem, Pa., from 1876 to 1895, has been in progress with the view to its publication in a complete and final form. The first fasciculous of this publication appeared in the spring of 1901 and it is hoped that the remainder may be in form for the printer in the course of two or three months.

The present communication deals primarily with the value of the constant of aberration resulting from the series of observations extending from October 10, 1892, to December 27, 1893. A preliminary solution of the problem was published in the *Astronomical Journal,* No. 406, 1897, which may be consulted for a fuller statement as to the method employed. The micrometer screw had become much worn by constant use for several years and the value was not constant throughout the series. Also the progressive errors which had been previously determined by means of Harkness' measuring engine were no longer applicable. It seemed very desirable that the screw value should be derived from the latitude observations themselves, but at the time spoken of the star declinations were not known with the requisite precision. For these reasons there was some hesitation as to the desirability of publishing the preliminary result, as it was thought possible that a considerable error might be involved. Recently a very careful discussion of the declinations has furnished the required data, and a result obtained which seems entirely free from the above named objections.

From the method of observing it is not possible to separate the correction to the aberration constant from the latitude variation without introducing an assumption with respect to one or the other. It has accordingly been assumed that the latitude variation can be represented by two periodic terms of 14 and 12 months, respectively. Each observed latitude, therefore, gives an equation of this form.

$$x \sin N + y \cos N + z \sin \odot + u \cos \odot + E\rho + T\mu + \Delta\phi + \phi_0 = \phi$$

where N is the 14-month term, $E\rho$ the correction to the aberration and $T\mu$ the secular change in the latitude.

The evening and morning observations furnish 1,744 and 1,052 equations of this form, respectively. These were solved retaining all terms. Then another solution was made excluding the annual term, as it is obvious that this can not be separated from the 14-month term in a series embracing a period of less than 16 months. The resulting value of the constant of aberration from both the preliminary and revised solution is as follows:

	Preliminary.	Revised Solution.
1st solution,	20″.552 ± .0095	20″.551 ± .0092
2d solution,	20 .555 ± .0093	20 .552 ± .0090

It thus appears that the suspected error in the preliminary reduction was a vanishing quantity.

Two other series of observations made at the Sayre Observatory have been employed for a similar investigation. The first, from December 1, 1889, to December 13, 1890, embracing 1,344 latitude determinations, was treated in a manner similar to that above described except that only one solution was made involving periodic term of 14 months. The resulting aberration constant is 20″.448 ± .014. It is doubtful whether this result is entitled to much confidence, the most serious objection being that the series does not cover a full term of 14 months, which is assumed for the period of latitude variation. The other series referred to extends from January 19, 1894, to August 19, 1895, the arrangement being that sometimes called the polygon method by which the aberration is obtained independently of the latitude variation. The result is 20″.537. Other recent determinations are given for comparison:

Flower Observatory.

1896-98	20″.580
1898-99	20 .542
1900-01	20 .560

J. W. J. A. Stein, Leiden—Zenith Telescope.

1899-1900 .... 20″.541 ± .016

Albrecht—International Latitude.

20″.515

Chandler from Pond's Observations.

1825-36 .... 20″.512 ± .019

THE PERIOD OF DELTA EQUULEI.

BY W. J. HUSSEY.

Delta Equulei enjoys the distinction of having a period shorter by nearly half than that of any other visual double star and in being at the same time a spectroscopic binary. The latter characteristic is due to the visible components. It therefore forms a connection between the visual and spectroscopic double stars. This pair was discovered in 1852 by Otto Struve and observed by him occasionally for thirty years. Burnham's observations from 1880 to 1883, inclusive appeared to indicate a period of 10.8 years; the elements subsequently derived by Wroublewsky and by See gave nearly 11.5 years. Between 1899.85 and 1900.65 the components rapidly approached each other and the apparent distance was extremely small at the latter date. This rapid change in distance is not explainable on the hypothesis that the period is nearly 11.5 years, but is entirely in accord with one of about half this length. The elements derived by the writer a year ago have a period of 5.7 years. From these elements he predicted that the components should separate to a measurable distance this year and again close in. Observations show that this has happened. In July, 1901, the distance was approximately 0″.15. It has now decreased to less than 0″.05, or approximately the same as in the autumn of 1900. The data at present available appear to show that the period of 5.7 years is substantially correct.

THE DURATION OF TWILIGHT WITHIN THE TROPICS.

BY S. I. BAILEY.

The atmosphere renders many services to man. Not the least of these, perhaps, is the twilight. If there were no atmosphere, there would be no twilight, and the brightness of midday would be succeeded, the moment after sunset, by the darkness of midnight. Such a condition of affairs would cause considerable inconvenience. Twilight may be said to last until the last bit of illuminated sky disappears from the western horizon. In general it has been found that this occurs when the sun has sunk about 18° below the horizon. The duration of time which the sun takes in reaching this position is very different at different latitudes. At the North Pole one would have about six months of daylight, followed by nearly two months of decreasing twilight, followed in turn by more than two months of night. In summer, at latitudes greater than 50°, twilight lasts from sunset to sunrise. There is no night there, during this season. In the temperate zones the duration of twilight ranges from an hour and a half to more than two hours. Within the tropics the sun descends nearly or quite vertically; but even here the time required for the sun to reach a point 18° below the horizon is more than an hour. There seems to be no reason, therefore, in the general theory, for the widespread belief that the duration of the tropical twilight is extremely brief. This idea is found not only in current popular literature, but also in some of the best text-books on general astronomy. Young's *General Astronomy,* p. 69, says: "At Quito and Lima it (the twilight) is said to last not more than twenty minutes." Why Quito should be classed with Lima I do not know, except that both are within the tropics. *The Heavens Above,* by Gilbert and Rolfe, remarks: "Within the tropics, where the air is pure and dry, twilight sometimes lasts only fifteen minutes." Since Arequipa, Peru, lies within the tropics and has an elevation of 8,000 feet, and the air is especially pure and dry, the conditions appear to be exceptionally favorable for an extremely short twilight. On Sunday, June 25, 1899, the following observations were made at the Harvard Astronomical Station, which is situated there: The sun disappeared at 5:30 p. m., local mean time. At 6:00 p. m., 30 m. after sunset, I could read ordinary print with perfect ease. At 6:30 p. m. I could see the time readily by an ordinary watch. At 6:40 p. m., 70 m. after sunset, the illuminted western sky was still bright enough to cast a faint shadow of an opaque body on a white surface. At 6:50 p. m. the illumination was faint, and at 6:55 p. m., 1 h. and 25 m. after sunset, it had disappeared. On August 27, 1899, the following observations were made at Vincocaya. The latitude of this place is about 16° south, and the altitude 14,360 feet. Here it was possible to read coarse print 47 m. after sunset, and twilight could be seen for an hour and twelve minutes after the sun's disappearance. It appears, therefore, that while the tropical twilight is somewhat shorter than occurs elsewhere, and is still further lessened by favorable conditions, such as great altitude, and a specially pure air, it is never less, and generally much longer, than an hour.

THE DETERMINATION OF DOUBLE STAR ORBITS.

BY GEORGE C. COMSTOCK.

The usual data for the determination of a double star orbit consist of a series of observed position angles and distances with the corresponding times of observation. From these data it is customary to derive the apparent orbit of the star by plotting the observed coordinates and drawing through the resulting points the best ellipse that can be fitted to them, subject to the condition that in this ellipse the radius vector must sweep over equal areas in equal times. The author knows no published statement showing how this condition is applied in the actual construction of the ellipse and it is not apparent how it can be applied in any satisfactory manner in this purely graphical process. Moreover, the process is open to the additional objection that it takes small account of the circumstance that of the three elements entering into a complete double star observation, position angle, distance and epoch, the time of observation is determined with a precision incomparably superior to that of the measured coordinates, and should therefore play a prominent part in the determination of the orbit instead of the subordinate role commonly assigned it. The method proposed for improving the current practice in these respects reverts to the practice introduced by Sir John Herschel, of plotting the observed position angles with the corresponding times as abscissæ, and extends the same practice to the observed distances. From the resulting curves data are derived for assumed epochs, and through a least square adjustment supplemented by mechanical quadratures are transformed into normal places that satisfy rigorously the condition of constant areal velocity. A partial control upon the character of the data and the treatment to which they have been subjected is furnished by the quasi rigorous condition that the adjusted normal places shall all lie upon some ellipse. In the adjustment of the data there is incidentally determined the areal velocity of the radius vector and this in connection with the apparent orbit, plotted from the normal places, leads immediately to a determination of the periodic time and to the independent determination of the dates of periastron and apastron passage. The agreement of the double interval between these dates with the periodic time first determined furnishes a partial check upon the work. The transition from the apparent to the real orbit may be made by any of the standard methods, but that of Klinkerfues when simplified by the introduction of the elements above derived is especially convenient. There was presented an application of the method above outlined to the determination of the orbit Σ 2107, showing that the labor involved does not greatly exceed that of the ordinary methods and is fully compensated by the checks furnished *en route* as well as by the increased precision of the results.

A COSMIC CYCLE.

BY FRANK W. VERY.

An application of a new doctrine of an explosive condition of matter (limited by composition, pressure and temperature) to various phenomena of the heavenly bodies, and to stellar evolution. Novæ are regarded as the culmination of long-enduring antecedent stages of stellar preparation, and as indicating (along with the helium stars) a condition of instability and active modification which is incompatible with planetary growth, but which is followed by other relatively quiescent stages favorable to the production of planets and to their orderly development. An extension of the doctrine of the conservation of energy is involved, and the problem of the sustentation of solar heat is approached from a new standpoint which admits of a great extension in the duration of the solar system, thus satisfying the demands of the geologist for a prolonged terrestrial duration.

A COMPARISON OF PRINTING AND RECORDING CHRONOGRAPHS.

BY C. S. HOWE.

A printing chronograph, to be of any value to astronomers, should be easily set and regulated; it should run several hours without any attention ; it should have a small probable error; its results should agree, or differ by a constant amount each night, with the results from the recording chronograph. Several months' experience with the Hough printing chronograph at the Case Observatory shows that the instrument can be easily set and adjusted and that it runs several hours without any attention. The probable error of one record was found to be ± .011 seconds, and the probable error of the mean of nine wires ± .004 seconds. Similar tests with the recording chronograph give respectively ± .006 and ± .022 seconds. These errors are so small that they can be neglected. A direct comparison of the two chronographs showed an average difference between them of .025 seconds, the printing chronograph making the record first.

THE CLOCK ROOM OF THE CASE OBSERVATORY.

BY C. S. HOWE AND E. H. BROWN.

The clock room is a room built of tile within one of the rooms of the basement of the Physical Laboratory. The basement is warmed in the daytime, but not at night. The space outside the clock room is warmed by two gas stoves, the gas being turned on or off by an automatic burner which is regulated by a thermostat made of steel and hard rubber. This controls the temperature outside the clock room within one degree centigrade and inside the clock room within about one-half degree. The inside temperature is further controlled by another thermostat, which by means of a relay throws in or out one or more electric lamps, the heat of which changes the temperature. This arrangement keeps the temperature within one tenth of a degree. The hourly rates of a Riefler clock, enclosed in a glass case from which the air is partially exhausted, were also given.

THE ALMUCANTAR AS AN INSTRUMENT FOR THE DETERMINATION OF TIME.

BY C. S. HOWE.

In 1885 Dr. Chandler compared the clock corrections determined with a small almucantar with those determined with the large Transit Circle of the Harvard Observatory. The Case Almucantar is a large instrument with a six-inch object glass. It was not possible to compare it with a large transit and so its value for the determination of time could only be determined by the consistency of the several results obtained on any one night and by the excellent and nearly uniform clock rates determined by it. The differences between the several values of the clock correction on any one night were usually not more than two or three hundredths of a second and the greatest difference since June, 1901, was 0.13 of a second.

A DESCRIPTION OF THE SECOND (CHILE) MILLS SPECTROGRAPH.

BY W. W. CAMPBELL.

The mechanical features of the instrument and its method of support are radically different from those of the conventional spectrographs. The entire frame-work is composed of a single steel casting with webs and flanges bracing it thoroughly in every direction and with especial reference to the supports near its two ends. The slit, the prism box, the camera and the collimator and camera lenses are all fixed directly to the casting. A reflecting slit is used, curved to make the spectrum lines straight. The weight of the entire spectrograph is about seventy-five pounds. The instrument is mounted in a supporting cradle composed of tee and channel steel bars in such a way that it will rest on two points (a plane and a ring) near the two ends of the instrument, respectively. Strains in the supporting cradle cannot induce strains in the spectrograph. The old method of supporting spectrographs entirely from one end, allowing the other end to project unsupported out into space, invites flexure effects, and it is hoped that the new method of support will prove to be a radical improvement. The whole spectrograph will be moved to bring the slit into the focus of the Cassegrain telescope. A temperature case similar to the one used for the past three years on the original Mills spectrograph will enclose the instrument.

ON THE CAPTURE OF COMETS BY JUPITER.

BY PERCIVAL LOWELL.

This paper gave in diagrams a part of the author's memoir on the subject, not yet published, in which he explained the action of Jupiter upon a comet entering the planet's sphere of activity, and the relation borne by the direction and the speed of approach to the comet's subsequent behavior. The paper showed that Jupiter was not only capable of transforming at one encounter a parabolic comet into an elliptic one of about half his own major axis, but could actually cause a comet to make the planet instead of the sun the goal of its visit, and send it back again into space without circumnavigating the sun at all. The argument then developed a critical angle differentiating those comets which Jupiter's action might render retrograde from such as it could not. A table here showed that the angle of approach of each of the comets composing Jupiter's comet family not only at the present moment fell within the critical angle for each, but must do so for all time, abstraction made of perturbations by other bodies and the approximation being of the first order. In other words, that under these conditions the present direct motion of all the members of Jupiter's comet family was such in perpetuity. The planet might drive them off into space but could never render any of them retrograde.

THE LATITUDE-VARIATION OBSERVATORY OF THE INTERNATIONAL GEODETIC ASSOCIATION.

BY HERMAN S. DAVIS.

A brief statement of the plan of the International Association in the establishment of the four stations at Gaithersburg, Maryland, Ukiah, California, and in Japan and Sardinia for a systematic and continuous series of observations for the study of variations of latitude. Particular attention was given to the two stations in the United States under the general direction of the Coast and Geodetic Survey, the one in charge of Dr. Schlesinger, at Ukiah, and the other in charge of the speaker, at Gaithersburg. Illustrations with the lantern were shown of both these stations with plans of the buildings and views of the telescope at Gaithersburg. Attention was called to the admirable quality of the observations made by Mr. Edwin Smith, who was in charge of the station at Gaithersburg prior to January, 1901, and entire credit given him for the erection of the buildings and installation of the instruments at this station, and to the active and enthusiastic support of the superintendent of the Coast Survey from the very inception of the plan to establish these stations in the United States.

SOME VICES AND DEVICES IN ASTRONOMICAL COMPUTATIONS.

BY HERMAN S. DAVIS.

Owing to the briefness of the time requested for the presentation of this paper and the fact that a considerable portion of that time was devoted to the preceding paper which was presented by request—not being regularly on the program—the speaker gave only a meager description of some of the methods which he is now using in the new reduction of the 160,000 star-observations made by Piazzi at Palermo between 1792 and 1813. Particular attention was directed to only one of the many devices which have been applied for shortening the computations whereby already the work is two years ahead of the schedule outlined at the beginning of the undertaking, that device being the use of specially constructed tables of limiting-values instead of such logarithm or antilogarithm or other tables as appear in print. Illustrations of these special tables and their application and data as to the percentage of time saved by their use were also given. Another one of the devices has already been published in *Astronomi-*

cal Journal, No. 498 (XXI:143-4), and a number of others, of which mention was omitted for lack of time and the lantern slides which had been designed (but unexpectedly delayed) for their proper exposition will be put into print at some future date.

OBSERVATIONS OF METEORS, NOVEMBER 13-16, 1901.

BY J. K. REES.

As in previous years, I observed with Mr. Charles A. Post from his observatory at Bayport, Long Island. We arranged (1) to photograph meteor trails with four cameras mounted on the equatorial which was driven by an excellent clock, (2) to count the meteors and (3) to record individual meteors which exhibited striking peculiarities.

1. The equatorial and cameras employed are shown in Plate II, *Popular Astronomy,* February, 1901.

The apertures and focal lengths are given in the following table:

Instrument.	Aperture.	Focal length.
Equatorial telescope.	6 inches.	90 inches.
Willard photographic doublet.	5½ "	23 "
Darlot portrait.	1½ "	6½ "
Anthony portrait.	3 "	13½ "
Goerz wide angle double anastigmatic.	1½ "	9½ "

PHOTOGRAPHIC EXPOSURES.

Nov. 13. 12:00 to 18:00 (Eastern Standard Time). A number of experimental plates were taken but no effort was made to photograph meteors, as few were seen.

Nov. 14. 11:20 to 12:24. Exposed the Goerz lens pointed at the belt of Orion. 13:15 to 14:05. Exposed all the cameras as follows: Willard and Anthony lenses at Procyon, Goerz lens at belt of Orion, and Darlot lens at μ and ϵ Leonis. At 15:00 the sky clouded but cleared again at 15:30. 15:42 to 16:30 all cameras were exposed. The Willard and Anthony on ϵ Leonis, the Goerz on ζ, ϵ, δ Hydræ, and the Darlot on Ursa Major.

The clouds began to spread over the sky again, and in a short time it was impossible to see a star, later it cleared. Observers then confined their attention to counting and observing the meteors.

Nov. 15. 11:45 to 13:00. Exposed all cameras. Willard and Anthony lenses on Pollux, Goerz lens on Procyon, and Darlot lens on γ Geminorum. 14:35 to 15:45. Exposed all cameras. Willard and Anthony on ζ Leonis, Goerz on Regulus, and Darlot on λ and μ Leonis Minoris. Clock did not work as well as usual. 16:01 to 17:00. Willard lens was omitted. The other cameras were pointed as in the preceding exposure.

Mr. Post developed all the plates. The plates on November 14 show a number of trails. Quite a remarkable meteor trail is shown on the plates taken with the Willard and the Anthony lenses between 15:42 and 16:30. The notes given under 'Record of Individual Meteors' seem to show that this meteor appeared at 15:58.

2. Count of Meteors.

Only during the night of November 14 was any careful attempt made to count. Miss Edith Post and Miss Greenough observed the eastern sky looking toward the radiant. At first both observed the same part of the sky, but after thirty-eight had been counted Miss Greenough observed the southeastern sky from the line from the radiant to the zenith, and Miss Post observed the northeastern sky from the same line. The count was as follows:

Nov. 14. 12:15 to 13:40. Miss Post and Miss Greenough, 38; Miss Post —northeastern sky, 31; Miss Greenough—southeastern sky, 31. 13:40 to 14:20. Messrs. Post and Rees looking out of the opening in the roof of the Observatory toward the radiant, 20. 14:20 to 15:00. Miss Post—northeastern sky, 10; Miss Greenough, southeastern sky, 15. 15:50 to 17:55. The Misses Post and Greenough counted being assisted from 16:30 to 17:55 by Post and Rees. The total count of the four observers was 273. Total for the evening, 418.

Nov. 15. Post and Rees assisted by Mr. Post's 'handy man' counted, while engaged on the photographic work and looking out of the observatory opening, as follows: 11:45 to 13:00. 25, several of which were non-Leonids. 14:35 to 15:45. 3 of which 1 non-Leonid. 16:01 to 17:00. 23, several non-Leonids.

Nov. 16. 12:00 to 17:00. Looked out frequently but saw so few that no record was kept.

3. Individual Meteors.

Nov. 14. 11:30. Two bright Leonids—trails yellow-red 10° long—width very distinct. 11:51. Leonid from Procyon to θ Orionis—blue streak. 12:07. From star above Procyon to 'yardstick'—trail 25° long—lasted several seconds—yellow—Leonid. 12:10. Leonid through Ursa Major—bright trail. 12:15. Leonid through Ursa Major. 12:17. Leonid through Auriga. 13:18. Brilliant Leonid, near radiant—very small trail—through Auriga. 13:18. Brilliant Leonid, near radiant—very small trail—orange color—bright as Mars at best. 13:27. Fine Leonid from Leo to zenith—trail 30° long—yellow-red. 13:30. Leonid through Ursa Major—fine. 13:40. Meteor near Procyon—from zenith down—short trail. 13:44. Fine Leonid through bowl of dipper—trail 5°. 13:51. Leonid under Procyon —8° trail—yellow-red. 15:58. Brilliant Leonid—trail 5°—lasted twenty seconds—blue-white—1st magnitude. 16:04. Leonid under Procyon—blue-white —10° trail. 17:28. Two brilliant meteors visible at same time—trails crossed —brilliant heads. One came from radiant and passed near α and β Can. Ven.—trail 30° long and lasted several seconds. The second seemed to come from below β Leonis and cut the tail of the first under Canes Venatici—trail 30°. Magnitude of each—2.

Nov. 15. 14:52. Bright Leonid under Leo Minor. 15:37. Leonid bright as Jupiter—in sickle—blue and red trail. About 15:55. Fire ball below Leo came from Orion. 16:10. From zenith through Leo Minor (λ and μ)—long train 40°. About 17:00. The zodiacal light showed itself in a grandly beautiful manner.

A THEOREM CONCERNING THE METHOD OF LEAST SQUARES.

BY HAROLD JACOBY.

The following theorem and conclusion are doubtless well known to many astronomers, but the writer has not found an explicit statement of them in print. Let there be given two series of observation equations as follows:

$$\left.\begin{array}{l} a_1x + b_1y + c_1z + \ldots + n_1 = 0 \\ a_2x + b_2y + c_2z + \ldots + n_2 = 0 \\ \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \end{array}\right\} \quad (1)$$

$$\left.\begin{array}{l} a_1x + b_1y + c_1z + \ldots + p_1w + \ldots + n_1 = 0 \\ a_2x + b_2y + c_2z + \ldots + p_2w + \ldots + n_2 = 0 \\ \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \end{array}\right\} \quad (2)$$

the equations being identical in the two series except for the addition of one or more new unknowns, $w, \ldots$ in (2). Let each series of equations be solved by the method of least squares, and let $[vv]_1$ be the sum of the squares of the residuals resulting from the solution of equations (1), $[vv]_2$ be the sum of the squares of the residuals resulting from the solution of equations (2); then, no matter what may be the law of the coefficients $p_1, p_2, \ldots$, and even if these coefficients are assigned at random, $[vv]_1$ is always larger than $[vv]_2$.

Corollary.—The theorem can be extended easily to an additional case of equal importance. Instead of introducing the new unknowns $w, \ldots$, by adding them to those already occurring in equations (1), we may select out certain equations from the series (1), and simply substitute new unknowns, like w, for old ones, like z, leaving the coefficients unchanged.

Conclusion.—The method of least squares is used ordinarily to adjust series of observation equations so as to obtain the most probable values of the unknowns. But there is a subtler and perhaps more important use of the method; when it is employed to decide which of two hypothetical theories has the greater probability of really being a law of nature; or to decide between two methods of reducing observations. Cases abound in astronomy where the method of least squares is used for this purpose. It has been so employed, for instance, to decide whether stellar parallax observations should be reduced with equations involving terms depending on atmospheric dispersion, and terms depending on the hour-angle, to ascertain whether portable transit observations should be reduced on the supposition of a change of azimuth on reversal of the instrument (an application of the corollary), etc.

In such cases, astronomers not infrequently give preference to the solution which brings out the smallest value of $[vv]$, the sum of the squared residuals. But in the light of the above theorem, it becomes clear that the mere diminution of $[vv]$ alone is insufficient to decide between two solutions, when one involves more unknowns than the other. To give preference to the second solution it is necessary that the diminution of $[vv]$ be quite large, and that the additional unknowns possess a decided *a priori* probability of having a real existence.

THE NEBULA ABOUT NOVA PERSEI, 1901.

BY FRANK W. VERY.

The rapidly shifting and fast fading nebulosity around the new star is regarded as an evanescent phenomenon comparable to the tail of a comet. Velocities of propagation of different orders are surmised, but as there is no known motion of material particles, even when of the dimensions of negative ions, swifter than that of light, the latter may be taken as a limiting value of velocity, from which it is deduced that the distance of the nova can not exceed 750,000,000,000,000 miles, an estimate which gives us a first approximation to the distance of the Milky Way, since the novæ all belong to the galactic stream. An explanation of the meaning of the complex structure of the hydrogen bands in the spectrum of the nova is given, and a further cometary analogy is shown through the existence of concentric spherical envelopes near the star, resembling comæ, which are inferred from the structure of the spectral bands. From the spectral variations attending the formation and motion of these envelopes, the mass of the star is concluded to be about 1,150 times that of the sun; and as this mass does not appear to have been appreciably changed in the first month, in spite of the enormous outpourings of hot gases, it follows that the luminosity of the star is not conditioned by the mass or by the state of the star's internal activity; and it is suggested that the brightness of the star's continuous spectrum depends upon the formation or dissolution of clouds of cosmic dust in the spaces immediately surrounding the nova.

A SHORT AND GENERAL METHOD OF DETERMINING ORBITS FROM THREE OBSERVATIONS.

BY A. O. LEUSCHNER.

The method is principally intended to aid in the rapid determination of an orbit from three observations, made at short intervals. It is essentially an improvement on Harzer's modification of Laplace's method contained in *Mécanique Céleste* T. I, première partie, livre II, Chap. IV. The first part of the paper deals with the discussion of Harzer's method. The modifications introduced by the author consist in: (1) The restriction of the number of observations to three, the minimum number necessary for the solution of the problem. (2) The reduction of the number of fundamental data to be approximated. In Harzer's method the fundamental data to be approximated are the heliocentric coordinates and their velocities, while in the present method they are the geocentric distance and the velocities of the heliocentric coordinates, all for the zero date. (3) A short method of obtaining preliminary values of the geocentric velocities and accelerations at the zero date. (4) A direct solution of the fundamental equation of the seventh degree in ρ_0, on the basis of von Oppolzer's Table XIIIa (*Bahnbestimmung*, Vol. I). (5) Differential formulæ for the determination of the final values of the heliocentric coordinates and velocities from which the elements are computed by Encke's formulæ. Chief among the advantages of the method here outlined are the ease with which such corrections to ρ_0, x_0', y_0', z_0' may be determined as will cause the residuals due to the original values of these quantities to disappear, and the possibility of determining these corrections directly from the residuals. On that account, it is of no great consequence if the originally adopted velocities and accelerations in α and δ are only approximate.

ELEMENTS OF ASTEROID 1900 GA AND ITS EPHEMERIS FOR THE OPPOSITION OF 1901-1902.

BY A. O. LEUSCHNER AND ADELAIDE M. HOBE.

This asteroid was discovered June 28, 1900, by the late director, James E. Keeler, of Lick Observatory, while photographing the region of the sky near Saturn with the Crossley Reflector. Trails were photographed on four days and point-images on two of these days. The problem of determining the orbit of the asteroid presents many points of interest and has led to the derivation of the 'Short and General Method of Determining Orbits from Three Observations.' The existing methods for determining orbits could not be used to advantage in this case, but the solution was successfully accomplished by means of the 'Short and General Method of Determining Orbits from Three Observations' outlined above. The magnitude of the asteroid at the present opposition (1902, Jan. 4) is 19.5 ± .75. The asteroid is, therefore, the faintest so far observed. The paper concludes with the discussion of the residuals of the measured positions of the termini of the trails relatively to the middle of the trails.

DISCOVERY OF MOTION IN THE FAINT NEBULA SURROUNDING NOVA PERSEI.

BY C. D. PERRINE.

Early in the apparition of the new star in Perseus, short exposure photographs of it were secured with the Crossley Reflector by Messrs. H. K. Palmer and C. G. Dall. The first long exposure was secured on the nights of November 7 and 8. This negative had a total exposure of 7 h. 19 m. It was developed on the 9th, but owing to stormy weather was not dry and was not carefully examined until the morning of the 10th, when it was compared with the reproduction of a negative taken at the Yerkes Observatory on September 20 by Mr. Ritchey and published in the October number of the *Astrophysical Journal*, and the discovery at once made that several of the principal condensations in the nebula had moved to the southeast over a minute of arc in the interval. The main facts were embodied in a telegram which was sent to the Harvard College Observatory, for distribution to all observatories, at noon of November 10. A negative was obtained on the nights of November 12 and 13 with a total exposure of ten hours. A more rapid plate was used than on November 7 and

8 and with the longer exposure considerably more detail is shown. An exposure of 5 h. 28 m. was obtained on the night of December 4. As a storm came on, this plate was developed the following day. Considerable detail was shown on the negative and three of the condensations were seen to have moved appreciably, while the strong one nearest the Nova showed but little if any change. An exposure of ten hours was secured on the nights of December 8 and 11, the 9th and 10th being cloudy. The motion of the nebula is so rapid that even in this interval of three days, blurring in the best-marked condensation is noticeable. A comparison of the last negative with that of November 12 and 13 reveals a number of changes. Condensations *A, B* and *C* (*Lick Observatory Bulletin,* No. 10) have each continued their motions to the southeast full ½′. Condensation *D* shows little or no change. Perhaps it is moving nearly in line of sight. The negatives of December 4 and 8-11 show two new wisps of nebulosity southwest of the Nova at distances of 13′ and 14′, respectively. They are approximately arcs of circles of which Nova is the center and are about 2′ in length. They have been carefully looked for on the November negatives, but no traces are there found of them. Throughout the entire southeast quadrant faint nebulosity is shown to a distance of 18′ on the negative of December 8-11. There is but little appearance of structure in this outlying nebulosity. Several wisps of nebulosity 6′ to the north of Nova are sufficiently strong to show that motions outward of ¼′ to ½′ have taken place in the interval of twenty-seven days. A wisp 9′ to the north has also moved outward full ½′. Six minutes to the northwest of Nova is a wisp which has moved outward ¼′. None of these wisps to the north and northwest are well enough defined lengthwise to make the other component of motion certain in the interval. Directly to the west is an arrow-shaped mass of nebulosity resembling somewhat the structure of condensation *A*. It has certainly moved outward and there appears to have been a motion to the northwest. Many changes of form and intensity of masses of nebulosity have been noticed other than those referred to above, but which can not well be described. A longer series of photographs is necessary to deduce the character and amount of motion of these fainter masses. Lantern slides of the various photographs secured with the Crossley reflector were exhibited.

A DETERMINATION OF THE WAVE LENGTHS OF THE BRIGHTER NEBULAR LINES.

BY W. H. WRIGHT.

In the progress of our investigations upon the spectrum of Nova Persei (see *Lick Observatory Bulletin*, No. 8) there arose the necessity for a more accurate knowledge than then existed of the wave lengths of the brighter nebular lines. The spectra of the Orion Nebula and of three of the brighter planetary nebulæ have been photographed in some cases with one prism, and in other cases with three prisms, and the resulting plates have been measured and reduced. The wave lengths of sixteen bright lines have been determined with considerable accuracy, the fifth significant figure being determined definitely for the principal ones, and the uncertainty in the sixth place for the brighter lines being comparatively small. A slight correction appears to be needed in the values at present accepted for the positions of the two chief nebular lines determined by visual means. In the course of the work three new nebular lines have been discovered. The well-known lines usually described as $H\epsilon$ and λ 3727 have been found to be double.

A DETERMINATION OF THE CAUSE OF THE DISCREPANCY BETWEEN MEASURES OF SPECTROGRAMS MADE WITH VIOLET TO LEFT AND WITH VIOLET TO RIGHT.

BY H. M. REESE.

In this paper three possible causes of the effect in question are investigated: (1) The curvature of the spectral lines; (2) the position of the star-spectrum in the middle of the plate, enclosed by the comparison-spectrum; (3) a mere subjective tendency to set the cross-hair relatively farther to the right on a dark line in a white field than on a bright line in a dark field. The conclusion is reached that the third cause alone really operates, or at least that neither the curvature of the lines nor the relative position of star-spectrum and comparison affect the case.

FOUR NEW SPECTROSCOPIC BINARIES.

BY W. W. CAMPBELL.

Four stars have recently been observed with the Mills spectrograph to have variable velocities in the line of sight. These are ϕ Persei, ζ Herculis, α Equulei and o Andromedæ. The first of these is an interesting bright-line star. The second has a large radial velocity, and is moreover an interesting visual double star whose period is about thirty-three years. This therefore affords another connection between visual and spectroscopic binaries. In the case of the third star, a composite spectrum was observed a few years ago by Miss Maury at Harvard College Observatory. Thirty-two spectroscopic binaries discovered with the Mills spectrograph in the past three years had previously been announced, thus bringing the number up to thirty-six. On the list of suspected binaries are fourteen stars, awaiting confirmation. Before the discovery of these binaries, three had been found in the same list of stars by Belopolsky, making about forty spectroscopic binaries in three hundred and twenty-five stars observed. The proportion is therefore one spectroscopic binary for every eight stars observed. The variable velocity of our sun, due to its revolving planets, has a double amplitude of only a few hundredths of a kilometer. As the work progresses and the degree of accuracy attainable increases, we shall probably find that there is a regular gradation of double amplitudes from that of our sun up to those of the spectroscopic binaries already discovered, and it is possible that the star that is not a spectroscopic binary will prove to be the rare exception. This field of investigation is one of extreme richness.

DISCOVERY OF FIVE HUNDRED NEW DOUBLE STARS.

BY W. J. HUSSEY.

While observing the Otto Struve double stars the writer discovered new companions to five of them and also picked up several new pairs in the vicinity of others. This led to the notion of makin an extended search for new pairs, which was begun as soon as it was possible to do so without interfering with the work in progress. In the spring of 1899 search was commenced in a tentative way and in July of the same year it was taken up regularly, and since then has been conducted in a systematic manner. While only a part of the writer's time has been devoted to the consideration of new double stars, he has now discovered and measured five hundred new pairs having distances under five seconds. The work has been done with both the twelve and thirty-six-inch telescopes of the Lick Observatory. Many close and difficult pairs, some of them having distances less than a quarter of a second, having been found with the smaller instrument, but nearly all the measures have been made with the great telescope. The classification of the new pairs with respect to the distances between their components is as follows:

0″.25 or less,	37 pairs,
0 .25 to 0″.50,	96 pairs,
0 .51 to 1 .00,	112 pairs,
1 .01 to 2 .00,	112 pairs,
2 .01 to 5 .00,	143 pairs.

Seventy-one per cent. of the total number have distances under two seconds; forty-nine per cent. under one second; twenty-seven per cent. under half a second; and seven and one-half per cent. under quarter of a second.

ON THE DISCOVERY OF 300 DOUBLE STARS.

BY R. G. AITKEN.

The writer's experience in observing double stars led him to conclude that it was desirable to make a systematic search for new pairs. As a contribution toward such a piece of work, 10,917 stars brighter than 9.1 magnitude have been examined by him since April, 1899, with the result that 301 new double stars have been found. These all have distances between their components of less than 5″.00, 217 or 72 per cent. being closer than 2″.00, and 19 closer than 0″.25. The search has been made mainly with the twelve-inch telescope. The zones examined also contain 530 stars previously catalogued as double, but only 308 of these pairs are comparable with the new pairs with respect to the angular separation of their components. A new double star has been found for every thirty-six stars examined and one star in every eighteen examined is double within the adopted limit. On this basis it is estimated that more than three thousand close double stars, within the reach of the telescopes of the Lick Observatory, still await discovery.

A KINEMATIC STUDY OF HANSEN'S IDEAL COORDINATES.

BY KURT LAVES.

In the 'Auseinandersetzung' of Hansen the ideal coordinates are defined by the equations

$$X \,.\, d\alpha/dt + Y \,.\, d\beta/dt \;\; + Z \,.\, d\gamma/dt = 0$$
$$X \,.\, d\alpha'/dt + Y \,.\, d\beta'/dt \;\; + Z \,.\, d\gamma'/dt = 0$$
$$X \,.\, d\alpha''/dt + Y \,.\, d\beta''/dt \;\; + Z \,.\, d\gamma''/dt = 0$$

$\alpha, \beta, \gamma, \ldots \gamma''$ are functions of the time, the fixed coordinates x, y, z are connected with the movable coordinates X, Y, Z by means of the equations

$$x = \alpha X + \beta Y + \gamma Z$$
$$y = \alpha' X + \beta' Y + \gamma' Z$$
$$z = \alpha'' X + \beta'' Y + \gamma'' Z$$

Hansen joins to the conditions (1) the condition:

$$Z = 0$$

and obtains a well-defined system of ideal coordinates. Hansen has shown that the three homogeneous equations (1) lead to the following theorem: "In every ideal system of coordinates, referred to movable axes, the instantaneous axis of rotation coincides with the radius vector, drawn to the point." It is the intention of this paper to show that the last condition (3) will give rise to a kinematic theorem of similar import. Indeed, when we consider the three vectors, (1) the vector A of absolute acceleration of the point, (2) the vector of $A^{(r)}$ of relative acceleration of the point and (3) the vector $A^{(s)}$ of the acceleration of the movable system, we obtain for their components along the fixed axis three equations, of which only one is written down:

$$A_x = A_x^{(r)} + 2\,(dX/dt \,.\, d\alpha/dt + dY/dt \,.\, d\beta/dt + dZ \;\; dt \,.\, d\gamma/dt) + A^{(s)} \qquad (4)$$

Calling the middle terms on the right sides

$$R_x, \;\; R_y, \;\; R_z$$

respectively, and projecting them upon the movable axis, we obtain

$$R_x = -\,dY/dt \,.\, r + dZ/dt \,.\, q$$
$$R_y = -\,dZ/dt \,.\, p + dX/dt \,.\, r \qquad (5)$$
$$R_z = -\,dX/dt \,.\, q + dY/dt \,.\, p$$

p, q, r having their usual meaning.

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$$

will therefore be the moment of

$$\omega = \sqrt{p^2 + q^2 + r^2}$$

with respect to the point, which has for coordinates the quantities

$$dX/dt,\ dY/dt,\ dZ/dt\,.$$

Selecting the position of the XY plane to be that which coincides with the plane of this moment, we have two homogeneous equations of condition, namely,

$$\begin{aligned} -dY/dt\,.\,r + dZ/dt\,.\,q &= 0 \\ -dZ/dt\,.\,p + dX/dt\,.\,r &= 0 \end{aligned} \qquad (6)$$

it can be shown that these are equivalent to the one equation $Z = 0$. We derive therefore the following:

Theorem.—The condition $Z = 0$, which Hansen imposes upon his ideal coordinates, means that he selects for the XY plane the plane of the moment of the vector of instantaneous rotation with respect to the point of coordinates

$$dX/dt,\ dY/dt.$$

THE COMPUTATION OF LAPLACE'S COEFFICIENTS BY MEANS OF GYLDEN'S γ-COEFFICIENTS.

BY KURT LAVES.

In this paper it is shown, how the quantities $b^{(i)}$ and $c^{(i)}$ can be determined by means of the definite integrals ${}_s\beta^i$ tabulated by Gyldén in his Hülfstafeln (after multiplication with functions of the argument α). A comparison is made with the table of Runkle, formerly used for this purpose.

ASTRONOMICAL PHOTOGRAPHY WITH THE FORTY-INCH REFRACTOR AND THE TWO-FOOT REFLECTOR OF THE YERKES OBSERVATORY.

(*Illustrated with Lantern Slides*).

BY G. W. RITCHEY.

The forty-inch refractor, which was designed for visual observations, has been made available for photography through the use of a color screen and isochromatic plates. The greenish-yellow screen, placed in contact with a plate sensitized for light of this color, permits only those rays to pass for which the object glass is corrected. For all but the briefest exposures a double-slide plate-holder is employed. By means of two screws, which move the plate and guiding eye-piece, a star just outside the field being photographed is kept at the intersection of two spider lines throughout the exposure. In this way irregularities in the driving of the telescope, changes in refraction, etc., are corrected. The resulting photographs of the moon, Orion nebula, star clusters, etc., are exceedingly sharp, and are well adapted for measurement on account of their great scale. The two-foot reflector, on account of its short focal length (8 feet) and its freedom from chromatic aberration, is adapted for a different class of work, in which it admirably supplements the forty-inch refractor. All parts of this reflector were constructed at the Yerkes Observatory. On account of the perfect driving of the clock, permanence of collimation of the large mirror and freedom from flexure in the mounting, photographs of excellent definition are easily obtained. Among those exhibited were the Andromeda nebula, the Orion nebula, nebulæ in the Pleiades, and the expanding nebula surrounding Nova Persei.

A REMARKABLE DISTURBANCE OF THE SUN'S REVERSING LAYER.

BY GEORGE E. HALE.

A series of photographs of the solar spectrum, taken at the Kenwood Observatory in February, 1894, shows that the reversing layer surrounding a sun-spot was the scene of a great disturbance, which lasted only a few minutes. The diameter of the disturbed area was not less than one-sixth that of the sun. Over this entire region the dark lines of the solar spectrum were for a short time so changed in appearance as to be wholly unrecognizable. Measurements of the photograph show that nearly all of these lines occur in the normal solar spectrum, and that the changed appearance is due to great changes of relative intensity. Thus numerous lines barely visible on Rowland's map were for a short time very intense, while others, such as the aluminium line of intensity 20 at λ 3961.674, disappeared entirely. Two sharp bright lines appeared at λ 3884.67 and λ 3896.21. These were strongest in the spot and did not extend to the limits of the disturbed area. Full details are published in the *Astrophysical Journal,* Vol. XVI, p. 220 *et seq.*

THE BRUCE SPECTROGRAPH OF THE YERKES OBSERVATORY.

BY EDWIN B. FROST.

The equipment of the Yerkes Observatory has been recently enlarged by the completion of a spectrograph designed for the special purpose of the determination of the motion of the stars in the line of sight. The addition of this instrument to the accessories of the forty-inch telescope was made possible by the liberal gift of $2,300 from Miss Catherine W. Bruce and $500 from the Rumford Fund of the American Academy of Arts and Sciences. The spectrograph is very rigidly constructed, chiefly of iron and steel, and the prisms are maintained in a fixed, invariable position. The whole instrument is inclosed in a large aluminium case with double walls, for protection against changes of temperature. Coils of wire inside this case can be heated by the 110-volt current of the observatory mains, and it has been found not difficult to keep the temperature of the air in the prism-box within 0°.1 C. during exposures of an hour or more. A correcting lens placed one meter in front of the slit makes the visual forty-inch object-glass efficient for the violet light (λ 4500) which passes through the prism-train at minimum deviation. The collimator is of 2 in. aperture and 38 in. focus; and two cameras are provided, one of 3 in. aperture and 24 in. focus and another, a Zeiss anastigmat, of about 2.8 in. aperture and 18 in. focus. The first three lenses are of triple construction, designed by Professor C. S. Hastings and made by Brashear. It has proved to be a matter of great difficulty to obtain prisms of the large size necessary to transmit a two-inch beam which are sufficiently homogeneous. (The face of the largest prism is 133 mm. long and 57 mm. high). After an unsuccessful experience with a set of prisms of what appeared to be excellent glass from Mantois, a quantity of glass was ordered from Schott & Co., of Jena, which should be finely annealed and of the quality of telescope objectives, a requirement which, strangely enough, does not appear to be customary in respect to glass for prisms. This new set of prisms shows considerable improvement over the first ones, but the definition is still not the same over the whole surface of the faces. This is now assumed to be due to the moulding of the prisms in triangular shape at Jena instead of melting disks, as we had desired, from which the prisms would be cut by Brashear. Although the spectrograph does not fully realize the resolution which the length of the faces of the prisms would imply, the instrument has nevertheless been shown to be capable of furnishing results of a very high degree of accuracy, as illustrated in the paper by an example of a plate of α Arietis. The comparison spectra so far employed have been the spark of titanium and of iron and the helium tube. During the exposure on a star the observer guides the telescope by light reflected from the speculum slit jaws, which are not in the same plane, but symmetrically inclined away from the line of collimation, each making with it an angle of 92° 55′. It is also possible, by merely turning a mirror, to observe in the same guiding telescope the light that has gone through the slit and has been reflected at the first surface of the first prism. The method of measuring and reducing the plates briefly described by the writer at the meeting of the Society in 1899 is still in regular use. Plates are measured both with violet to right and with violet to left under the measuring microscope, as an observer may have a large systematic difference in his mode of making a setting on the dark lines of the comparison spectrum and the white lines of the stellar spectrum (on the negative). The writer has a large systematic error of this kind, which is reversed in sign but of the same size when the measures are made on a positive copy of the negative. By measuring the plate in both directions this systematic difference appears to be wholly eliminated. Each plate is reduced by itself, independently of any standard plate of a solar or metallic spectrum, with the aid of the Cornu-Hartmann formula in its simple form, the 'fit' of which can be checked up at the position of each comparison line and the wave-lengths corrected accordingly. The first star found by the Bruce spectrograph to be a spectroscopic binary is η Orionis. Four of the plates, taken by Mr. W. S. Adams and the writer, yield the following velocities:

1901,	Nov. 27,	— 68	km.	per	second.
	Dec. 6,	+ 13	"	"	"
	Dec. 18,	+ 54	"	"	"
	Dec. 19,	— 56	"	"	"

The period is not yet determinate. In concluding the paper the proposal was made that the six or seven observatories, which now include in their work the determination of stellar velocities in the line of sight, should cooperate in regularly observing a short list of fundamental velocity stars. The comparison of the results obtained for the same stars with the different spectrographs and different observers, using different sources of comparison spectrum and different lines of the stellar spectra, could hardly fail to be of great value both in indicating causes of error in the separate instruments and in establishing with a high degree of accuracy the velocities of these fundamental stars. (Published in *The Astrophysical Journal,* Vol. XV, pp. 1-27).

UNITED STATES NAVAL OBSERVATORY ECLIPSE EXPEDITION TO SUMATRA.

BY A. N. SKINNER.

ON THE PRESSURE OF LIGHT AND HEAT RADIATION.

BY E. F. NICHOLS.

THE MASS OF TITAN AND ITS PERTURBATIONS OF HYPERION.

BY W. S. EICHELBERGER.

FOURTH MEETING

The second winter meeting of the Astronomical Society was held in Washington, D. C., beginning on Monday, December 29, 1902, and continuing until the following Thursday, in affiliation with the American Association for the Advancement of Science.

One Monday afternoon more than two hundred persons assembled in the lecture room on the first floor of the Law Building of the Columbian University to hear the opening address by the President of the Society, Professor Simon Newcomb.

Three sessions of the Society for the reading of papers and the transaction of business were held in the Assembly Hall of the Cosmos Club, Tuesday, Wednesday, and Thursday afternoons. The average attendance at these sessions was about seventy-five.

The annual dinner was given at Maison Raucher on Tuesday evening, with forty-three persons present, including a number of ladies, and, as guests, His Excellency, the Imperial German Ambassador; the Assistant Secretary of State; United States Senator, Hon. J. T. Morgan; the Superintendent of the United States Naval Observatory, Captain Chester. A most enjoyable evening was spent together, and among the good things were the addresses by guests, by Professor Newcomb, and by Professor Hale.

On Wednesday afternoon the session was adjourned shortly before four o'clock, to enable the members of the Society to attend a reception given them at the Naval Observatory by Captain and Mrs. Chester. After a most pleasant social gathering of an hour or more, all present were invited to spend as much of the evening as they desired in an inspection of the Observatory and its equipment.

At the final session resolutions were adopted tendering the thanks of the Society to Captain Chester for his courteous invitation to visit the Naval Observatory, and his kind attentions during the meeting of the Society; also tendering the thanks of the Society to the Cosmos Club, for the use of the club house and all its facilities, so courteously accorded to the Society by its members.

On the last day of the meeting officers were elected as follows:

President	Simon Newcomb
First Vice-President	George E. Hale
Second Vice-President	W. W. Campbell

Secretary........................George C. Comstock
Treasurer..............................C. L. Doolittle
Councilors...................... { W. S. Eichelberger
Ormond Stone

Professor Eichelberger was chosen editor for the meeting.

ABSTRACTS OF PAPERS

COMPARISON OF ASTRONOMICAL PHOTOGRAPHIC MEASURES MADE WITH THE RESEAU AND WITHOUT IT.

BY HAROLD JACOBY.

The *réseau* method of measuring stellar photographs, as considered in the present note, is similar to that in use by the observatories participating in the photographic survey of the heavens now in progress. The most important advantage of this method of measurement is that it avoids almost altogether the effects of possible contractions or expansions of the sensitive film during development; and to this advantage has been joined another of a practical character which was perhaps not foreseen by the originators ot the *réseau* method. It is found most confusing to measure plates having nothing on their surfaces but star-images; in fact, in the case of close clusters, it is well-nigh impossible on such plates to make sure that the two coordinates assigned to any star really belong to the same object. All this possibility of confusion disappears, however, with *réseau* plates, as it is easy to keep all measures in order by considering each little square by itself.

As usual, there are compensating disadvantages connected with the *réseau*. It is necessary, for instance, to make certain assumptions, such as the following:

1. That the division errors of the original *réseau* can be determined as accurately as those of a scale.

2. That the photographic copy of the *réseau*, as it appears on the star-plate, really reproduces exactly the division errors of the original.

3. That the bisection of the photographed *réseau* lines on the star-plate can be made with a microscope as accurately as the lines of a scale can be bisected.

It is of course possible to discuss each of these assumptions separately; but in the present note I shall consider one simple experiment only. This consisted in measuring a couple of Pleiades photographs twice, once by the *réseau* method, and once with a metallic scale. A simple comparison ought then to show how far the two methods of measurement differ in their results. Seventy-five stars were observed in each case, and the same stars were used. The first plate was made at Paris, January 14, 1901, and the 'probable discordance' between the two methods of measurement was ± 0″.11. No corrections were applied for possible division errors of the Paris *réseau*, as none have been published, though the MM. Henry have satisfied themselves that the Paris *réseau* errors are inappreciable. The second plate was made at Helsingfors, December 12, 1900, and gave a probable discordance of ± 0″.22. In this case, the measures were corrected with Donner's division errors, but these are not large enough to affect the result appreciably. In both cases, measures made with the metallic scale were corrected for the division errors determined at Columbia University. The larger discordance in the case of the Helsingfors plate is probably due to the less well defined character of the photographed *réseau* lines. In many cases it is possible to bisect these lines under the microscope anywhere except at the corners of the squares, where two lines cross and form a point.

But when we consider that the above discordances involve the errors of both measurements, they do not appear unduly large. Divided by the square root of two, they give for the probable error of a measurement by one method only ± 0″.08 for Paris, and ± 0″.16 for Helsingfors; and there is no evidence of a systematic arrangement of signs in the differences between the two methods. We may conclude, therefore, that plates measured by the *réseau* method and without it give identical results within a very narrow margin; nor does irregular distortion of the film appear to have affected appreciably the measures made without the *réseau*.

THE SPECTRA OF STARS OF SECCHI'S FOURTH TYPE.

BY GEORGE E. HALE, FERDINAND ELLERMAN AND J. A. PARKHURST.

In his early days of stellar spectra, Secchi divided the red stars into two great classes (his third and fourth types), whose spectra differ very markedly in their general characteristics. Subsequent investigations by Vogel and Dunér confirmed Secchi's conclusion with regard to the presence of carbon bands in the spectra of stars of the fourth type, but in view of the instrumental means employed it was impossible for these investigators to distinguish the individual lines in the spectra. An investigation of these stars was accordingly undertaken with a three-prism spectrograph, used in conjunction with the forty-inch refractor and the two-foot reflector of the Yerkes Observatory. Some two hundred and fifty photographs, ranging in exposure-time from a few minutes up to twenty-five hours, were made. They include the yellow and green as well as the blue regions of the spectra. A special study has been made of eight stars, in whose spectra the wave-lengths of several hundred bright and dark lines have been measured. The presence of bright lines, though suspected by Secchi, was denied by subsequent observers, but has been abundantly confirmed by the present photographs. Hitherto it has not been possible to identify these lines. A large part of the dark lines, however, have been found to be due to iron, titanium and various other substances. By the aid of these lines the radial velocities of the eight stars have been determined. The photographs bring out a marked resemblance between the spectra of the two classes of red stars, so far as the dark lines are concerned. Cyanogen is present in both classes, but carbon, either alone or in combination with oxygen, is absent from stars of Secchi's third type, while very conspicuous in stars of the fourth type. In both classes of stars the relative intensities of the dark lines in the spectrum of a given element seem to differ considerably from the corresponding intensities in the solar spectrum. This led to a comparison of the stellar lines with the widened lines in the spectra of sun-spots. So far as can be judged from the present photographs, there is a marked similarity of these spectra, but this can not be made the basis of any theoretical conclusions before further investigations with higher dispersion have been made. In general, the investigation tends to confirm the opinion of Vogel and Dunér that the two classes of red stars have developed from solar stars. Full details of the work, with tables of wave-lengths and reproductions of photographs, will appear soon in the *Publications of the Yerkes Observatory,* Vol. II.

RADIAL VELOCITIES OF TWENTY STARS HAVING SPECTRA OF THE ORION TYPE.

BY EDWIN B. FROST AND WALTER S. ADAMS

This paper represents a part of the work done during the past year with the new Bruce spectrograph of the Yerkes Observatory. Stars with spectra of this interesting type, which seems certainly to characterize an early stage of stellar development, have not hitherto received much attention in respect to motion in the line of sight.

These spectra are not adapted to measurements of any such degree of accuracy as is possible for the solar stars, because of the comparative fewness and the generally hazy and ill-defined character of their lines. The results have, however, proved more accordant than was anticipated. The general good adjustment and trustworthiness of the spectrograph are attested by the measures of the moon's radial velocity. The twelve lunar spectra photographed during the year gave a mean difference of two-tenths of a kilometer per second between the observed and the computed radial velocity, the largest difference being seven-tenths of a kilometer per second. The titanium spark was chiefly used for furnishing the comparison spectrum, but the iron and the chromium spark and a helium tube were also employed at times. A perfectly definite amount of self-induction and capacity was always maintained in the secondary circuit.

The lines commonly present and measured in the stellar spectra were those due to one or more of the following elements: helium, oxygen, silicon, nitrogen, hydrogen, magnesium. The observing list included about one hundred and fifty stars of this type brighter than the sixth magnitude. The present paper included only those of which three or more plates have been obtained and measured. Those found to vary in their radial velocity, six in number, were not included in the discussion. The stars of the Orion type are peculiarly distributed in the sky, being for the most part grouped in or near the Milky Way. As many of the twenty are near the apex or anti-apex of the sun's way, the observed velocities clearly show the effect of the solar motion. If a correction were applied for this motion, the resulting absolute radial velocities would be small. The angular proper motions of these stars are also small, and suggested a relatively great distance from our sun, as well as a 'community of interest' of these stars. The radial velocities observed, expressed in kilometers per second, are as follows:

γ Pegasi	+ 5	ε Can. maj.	+ 27
ζ Cassiopeiæ	+ 3	η Leonis	+ 4
ε Cassiopeiæ	— 6	γ Corvi	— 7
ζ Persei	+ 22	τ Herculis	— 13
β Orionis	+ 21	ζ Draconis	— 14
γ Orionis	+ 18	ι Herculis	— 16
ε Orionis	+ 26	67 Ophiuchi	— 4
ζ Orionis	+ 17	102 Herculis	— 11
κ Orionis	+ 17	η Lyræ	— 9
β Can. maj.	+ 33	ε Delphini	— 26

(This paper appears in full in Vol. II, of the *Publications of the Yerkes Observatory*).

NEW SPECTROSCOPIC BINARIES.

BY EDWIN B. FROST AND WALTER S. ADAMS.

During the observations described above, six stars of the Orion type were found whose radial velocity varied. Preliminary statements have been published as to three of these (η Orionis, *o* Persei, β Cephei). The others are δ Ceti, ζ Tauri and ν Eridani. Of δ Ceti we have obtained eleven plates since November 1, 1901, which give a range from + 6 to + 16 km. per second. The period is short, but observations on consecutive nights will be necessary for its establishment.

The plates of ζ Tauri available are ten in number (from November 8, 1901, to December 18, 1902), and give range from + 7 to + 34 km. The period can not yet be given, but may, perhaps, be about fourteen days. The spectrum is rather unique in respect to its very sharp and strong γ and β lines of hydrogen, with the other lines (some of them metallic) very faint.

One plate of ν Eridani was obtained in the autumn of 1901, and four a year later. The range of velocity so far observed is from + 3 to + 26 km. per second.

We regard two or three other stars with spectra of the Orion type as suspicious of variable radial velocities, but the number of plates so far obtained is insufficient to establish the variation. The proportion of spectroscopic binaries, found by us in this special class of stars, to the number of which we have obtained three plates is about one to five.

THE ORBIT OF THE SPECTROSCOPIC BINARY η ORIONIS.

BY WALTER S. ADAMS.

The variation in the radial velocity of η Orionis was discovered at the Yerkes Observatory in December, 1901, by Professor E. B. Frost and the writer. Since that time twenty-eight spectrograms have been secured, covering an interval of very nearly a year, and in the present paper the star's orbit is computed from them by the method of Lehmann-Filhés. The greatest range found is about two hundred and eighty-five kilometers, and is the largest which has hitherto been discovered among binaries which like this have one component dark. The spectrum is of the Orion type, but contains several silicon, oxygen and nitrogen lines as well.

The period used in plotting the observations is 7.9896 days, and the following elements are found:

Velocity of system $V = + 35.5$ km.
$u_2 = 90^\circ\ 41'.6$
$w = 42^\circ\ 16'$
$e = 0.016$
$\mu = 45^\circ.059$
$T =$ 1901, December 1.821
$a \sin i =$ 15,901,000 km.

An ephemeris is computed with these elements, and the greatest difference between the observed and computed velocities is found to be less than three kilometers.

THE MASSES IN 85 PEGASI.

BY GEORGE C. COMSTOCK.

Eighty-five Pegasi is a sixth magnitude star with an eleventh magnitude companion distant less than a second of arc. Burnham, who discovered the pair in 1878, has published an orbit with a periodic time of 25.7 years. The bright star of the pair has been frequently compared with a neighboring ninth magnitude star, and from a discussion of these measures covering a period of fifty years I find for the masses of the sixth and twelfth magnitude stars the ratio, 2:3, the faint star having the greater mass, although its light is only a hundredth part that of the brighter star.

The result is directly opposed to the common view that regards the fainter component of a binary star as more nearly extinct than its companion, because a smaller mass has caused it to traverse more rapidly the stages of development that lead to extinction.

STELLAR REVOLUTIONS WITHIN THE GALAXY.

BY FRANK W. VERY.

Independent estimates of the parallax of Nova Persei give

$$\pi = 0''.052, \quad \text{and} \quad \pi = 0''.049,$$

whence it is concluded that the distance of this presumably galactic object is about 600,000,000,000,000 km. It is proposed to adopt this distance as a first approximation to the sun's distance from the Milky Way.

The first-type stars, of which the galactic stream is mainly composed, probably have rather small linear velocities, and are the result of agglomerative tendencies; but around the central condensations there is a great sphere of stars, mostly in advanced stages of development, which seems to have been produced by stellar dispersal. These outlying stars may have been thrown off from the central condensations by explosions of great magnitude; and if the velocity of recession is not too great, these stars thenceforth revolve around controlling centers, consisting of densely clustering stars, in periods embracing many millions of years.

The attraction of spherical mass of stars, equivalent to 10,000,000 such suns as ours, the aggregate extending to ten times the assumed solar distance from the Galaxy, is sufficient to produce the present solar velocity (20 km. per sec.) in moving from rest at the outer limit, and to give an oscillation from one extreme to the opposite boundary in a little over 40,000,000 years. With a central galactic condensation sufficient to turn the movement into an eccentric orbital revolution, if apogalacteum is ten times as far away and perigalacteum one-tenth as far from the center of motion as the assumed galactic distance, the period of revolution will be shortened, but can not less than about 6,000,000 years for a circular orbit around a central cluster. The general stellar sphere controls the movement in an elongated orbit at the greater distances, but the massive central agglomerations exercise directive power at the closer approach.

There are certainly more than 10,000,000 stars. Hence, either their attractions are largely mutually annulled through symmetrical external position, or else most of the stars have masses very much less than that of the sun, which must be above the average mass.

As the true proper motions of the stars show little preference for particular directions, the dispersals have occurred indiscriminately in all directions.

The diverse regions of space traversed by the sun in its progression from perigalacteum to apogalacteum may have very different meteoric contents whose reception produces secular changes in the planetary atmospheres, and may influence the development of living forms indirectly.

The apex of the sun's way is now about twenty degrees from the axis of the galactic stream. At perigalacteum the apex will recede to the galactic pole, and the direction of motion of the apex in the interim will determine the axis of the solar orbit.

PRELIMINARY ANNOUNCEMENT WITH REGARD TO THE PROPER MOTIONS OF CERTAIN FAINT STARS.

BY GEORGE C. COMSTOCK.

The author has measured micrometrically the positions of forty-five faint stars (ninth to twelfth magnitudes) referred to brighter neighboring stars whose proper motions were accurately known. From a comparison of these observations with older data of a similar kind, principally the measurements made by the Struves, he has derived proper motions of the faint stars, which in respect of precision are quite comparable with the proper motions of the fainter fundamental stars, *e. g.*, those of the fifth and sixth magnitudes.

These proper motions, although relatively few in number, furnish a determination of the sun's motion in space entirely independent of all previous data, and based upon stars whose average distance from the solar system is much greater than any hitherto employed. The resulting solar motion is in substantial agreement with previous determinations, and when combined with spectroscopic determinations of the velocity of the sun's motion it furnishes as the mean parallax of the stars observed (magnitude 10.5) the value 0″.005 (40,000,000 radii of the earth's orbit) which is in substantial accord with the extrapolated value furnished by Kapteyn's researches upon the brighter stars.

Other results of the present investigation are: (1) That the proper motions of the fainter half of this list of stars do not seem to be materially less than those of the brighter half, *i. e.*, the eleventh and twelfth magnitude stars are not more distant than those of the ninth and tenth magnitudes; (2) that the average linear velocity with which these faint stars move through space is of the same order of magnitude as that of the brighter stars and about fifty per cent. greater than the velocity of the sun.

AN INQUIRY INTO THE CAUSE OF THE NEBULOSITY AROUND NOVA PERSEI.

BY FRANK W. VERY.

Lockyer's hypothesis of colliding meteor swarms would require spherical swarms of enormous dimensions, and in other respects it does not fit the facts. Radiation hypotheses do not explain the duplicity, or possible triplicity, of the nebulous ring, nor the double ratio of the radii of the two principal rings; neither is the retardation of the expansion satisfactorily accounted for. Reflection hypotheses are absolutely barred, because they demand an impossible albedo in the nebula.

The supposition that the motion is a real one involves the further hypotheses that it is due to particles of corpuscular dimensions, expelled from great masses of intensely heated gas, surrounding the nova, in moments of powerful electric oscillatory discharges; that these discharges assist to ionize the material and start a series of instantaneous magneto-electric impulses which guide the moving particles along lines of magnetic force; that the material is probably diamagnetic and will finally come to rest in loci of least magnetic potential; that the velocity imparted depends on the masses of the ions which appear to be in the ratio 1:2:4; that the velocity is accelerated out to a radius at which magnetic repulsion and gravitational attraction are equal for particles of the given dimensions, and that at greater distances the velocity is retarded. An estimate of the mass and diameter of the nova indicates that, at the surface of the star, the ratio of magnetic force to gravity may be as great as 100,000 to 1 for these minute particles; and as such a force would be capable of generating in a corpuscle a velocity of 100,000 km. per sec. in one second, if it were possible fully to utilize it for this purpose, the only objection which can be urged against the hypothesis is the difficulty of imagining a process by which this force can be economically applied.

In favor of the hypothesis it can be stated that the theoretical variation in the rate of expansion of the nebula has been observed; that the observed motions of nebulous forms agree well with those to be expected if the phenomenon is a species of magnetic phantom; that there are curved and diverging streamers on the south-southwest side, resembling the sheaves of diverging coronal filaments about the sun's poles; that the absence of a corresponding sheaf on the north-northeast side may be explained on Doppler's principle; that the disappearances of certain forms in the outer of the two principal rings after reaching a radius of 14′ to 16′, and the phenomenal and sudden appearance of bright forms at about the same positions, are to be explained on the same principle; that such appearances and disappearances are demanded on the magnetic hypothesis, and are extraordinary anomalies on any other.

It is concluded, therefore, that the nebula resembles a gigantic corona; that its axis is inclined forty degrees to the line of sight on the south-southwest side; and that the expansion of the nebula is approaching its limit.

THE MOUNTING OF FIXED MERIDIAN INSTRUMENTS.

BY G. W. HOUGH.

The variation in level and azimuth in fixed meridian instruments is due to the effect of temperature: (1) On the metal outside the piers, (2) on the metal in the piers, (3) on the supporting piers, and (4) to the motion of the base of the pier. In order to understand how the temperature acts on meridian instruments, we need some physical constants. If we assume the conductivity of iron as one, or unity, mercury is 1/10, stone, brick and wood 1/130 to 1/180. It will be readily understood that the iron outside of the pier will act quickly as a thermometer, the iron inside the pier will act more slowly, and the supporting piers will act very slowly in taking the temperature of the external air.

The piers acting as a thermometer may lag one month or more, and this is the explanation of the phenomenon observed at Edinburgh. Hence we conclude that variation of level and azimuth during a night of observation is almost entirely due to the effect of temperature on the metal parts of the instrument. The covering of piers with cloth and wood is of no use.

Many instruments in use change their level and azimuth by jumps, and not in any regular manner. If the expansion of iron is taken as unity, brass is 2, sandstone and granite 0.8 to 0.9, and bricks from 0.3 to 0.5. It is readily seen that the difference of expansion between brick and iron is so great that the instrument will always be loose on the piers. Hence it is free to jump in both level and azimuth.

In the Pistor & Martin's meridian circle the brass cylinder for holding the Y should be replaced with iron.

The modern Repsold is defective in its mechanical construction, for the reason that the Y-piece and the counterpose weight are all supported on one frame, and when the instrument is reversed it is liable to be disturbed in level and azimuth. The Dearborn Observatory old pattern Repsold meridian circle is mounted on sandstone piers, and the lugs for holding the Y-pieces are set in with lead. The instrument is absolutely stable in level and in azimuth. The computed monthly level for two years, when corrected for temperature and the motion of the pier, agrees with the observed level within a fraction of a second of arc.

THE PROBABLE VALUE OF THE CONSTANT OF ABERRATION.

BY S. C. CHANDLER.

The number of determinations of this constant is now so considerable that even wide differences of judgment as to the weights to be assigned them can have but little influence on the mean result. Forty-three determinations are combined with the following weights:

Talcott's method	20".523	Weight, 151
Meridian declinations	.514	22
Prime vertical transits	.525	24
Right ascensions	.53	6
Prismatic apparatus	.48	5
Mean	20".521	208

THE CONSTANT OF ABERRATION FROM OBSERVATIONS WITH THE ZENITH TELESCOPE, 1901-1902.

BY C. L. DOOLITTLE.

A preliminary reduction of the series of zenith telescope observations covering the period from October 1, 1901, to October 1, 1902, gives for this constant the value 20".510.

This is preliminary in the sense that some of the work of reduction has not been fully verified and that it is proposed to include in deriving the final result some additional data, viz., about four hundred observations between October 1, 1902, and January 1, 1903.

The values derived from the different series of observations at the Sayre and Flower Observatories are as follows:

(1)	1889–1890	20".448	±".014	Weight ¼
(2)	1892–1893	20 .551	± .009	1
(3)	1894–1895	20 .537	± .014	1
(4)	1896–1898	20 .580	± .008	½
(5)	1898–1899	20 .540	± .010	1
(6)	1900–1901	20 .561	± .008	1
(7)	1901–1902	20 .510		1
Weighted mean				20".539
Unweighted mean				20 .532

I have elsewhere given reasons for suspecting the genuineness of result (1). There are also reasons for the small weight assigned to result (4) aside from the somewhat larger value given.

It is proposed to continue this series for another year. It will then be terminated unless means can be had for giving the investigation a wider scope. For a number of years I have been hoping that I might be able to set up an instrument of different construction and have a second series of observations carried on simultaneously with my own for a period of at least two or three years. At present the necessary means are not available, but I have not entirely abandoned this project.

MICROMETRICAL MEASURES OF INDIVIDUAL STARS IN THE GREAT GLOBULAR CLUSTERS.

BY E. E. BARNARD.

The great power of the forty-inch refractor of the Yerkes Observatory has been utilized in a systematic micrometrical survey of between six hundred and seven hundred small stars in the globular clusters M 3, M 5, M 13 and M 92.

The paper deals mainly with the measures of stars in M 13 Herculis and a comparison of these with measures made by Dr. Scheiner, of Potsdam, in 1891, of photographs of the cluster. This comparison shows a generally close agreement between the photographic and visual measures. There are a few discordances amounting to one or more seconds of arc. There does not seem to be any proof that these are due to motion in these stars, but rather due to the difficulty of making the photographic measures. In ten years' interval there does not appear to be any certain proof of motion in any of the stars under observation. In the work with the large telescope the stars are referred to a standard star in each cluster. This star is accurately measured with reference to known stars, and its absolute position given, from which the exact place of any one of the smaller stars observed can be easily deduced. The measures were made by the method of position angle and double distances, though the relative positions of the stars to the standard stars are given in the order of $\Delta\alpha$ and $\Delta\delta$.

ON SOME OF THE VARIABLE STARS IN THE CLUSTER M 5 LIBRÆ.

BY E. E. BARNARD.

These are observations of some of the variable stars discovered in this cluster by Professor S. I. Bailey.

The smaller stars all have periods of nearly half a day, but there are three bright stars—the brightest in the cluster—which have relatively long periods. These periods are:

Star No.	Period.	Light Range.
42	25.7739 days	1¾ mag.
84	26.5760 "	1¾ "
50	106.17 "	1 "

The first two rise rapidly to maximum and decline slowly to minimum. No. 50, which seems to have the longest period in the cluster, differs markedly from the other two in that its rise and decline are both slow and uniform. All three are slightly yellowish at maximum.

Several of the small, quick-period variables were under observation. The best observed of these was No. 33, whose period is 0^d 12^h 2^m $7^s.6$, and whose light range is about one magnitude ($1^m.1$). The light curve for this star is rather remarkable.

The normal condition is faint at about 14½ mag. At about one hour before maximum it begins to rise. Its light increases rapidly, and the duration of maximum is very short. The star then declines about as rapidly as it rose, for about forty minutes. It then seems to halt in the decline, and from this on sinks very slowly to minimum, not reaching its faintest or normal condition until seven or eight hours after maximum.

NOTES ON THE SHORT METHOD OF DETERMINING ORBITS FROM THREE OBSERVATIONS.

BY A. O. LEUSCHNER.

In order to simplify the computation of preliminary orbits, the author proposes several modifications in the application of his 'Short Method, etc.' (*Publications of the Lick Observatory,* Vol. VII, part 1):

1. The accuracy of ρ_0 is increased by eliminating the parallax from the second observation through simple corrections applied to the corresponding solar coordinates in group I.

2. When the parallax factors for the three observations differ materially, the accuracy of the geocentric velocities is increased by applying the parallax corresponding to the unit of distance to all three observations in the formulæ of group II.

3. No correction for parallax is to be applied to the middle observation on the basis of the successive approximations for ρ_0 (cf. groups V, VII), but instead the parallax is to be eliminated once for

all by correcting the rectangular equatorial solar coordinates for the normal date as follows:

$$\begin{aligned}\Delta X &= \quad (p_1 \rho_0) \sin a_0 \cos \delta_0 + (p_2 \rho_0) \cos a_0 \sin \delta_0, \\ \Delta Y &= -(p_1 \rho_0) \cos a_0 \cos \delta_0 + (p_2 \rho_0) \cos a_0 \sin \delta_0, \\ \Delta Z &= -(p_2 \rho_0) \cos \delta_0,\end{aligned}$$

4. By replacing the A and B by

$$\begin{aligned}A' &= A + \cos \delta \, p_1/\rho^2, \\ B' &= B + p_2/\rho^2.\end{aligned}$$

respectively, in the differential formulæ (group VII), terms depending on the parallax factors are introduced which will minimize the effect, on the residuals, of changes in parallax, and the convergence is increased.

5. The sufficiency of the differential formulæ should be tested by checking the new residuals obtained in group VII by means of the corresponding formulæ of group VI.

6. Simple formulæ involving the squares of the corrections have been derived for those rare cases in which the linear relations are found to be insufficient.

7. The new values of x_0, y_0, z_0 (group VII) may be found rigidly in *all* cases by changing the former values by

$$\begin{aligned}dx_0 &= \cos a_0 \cos \delta_0 \, d\rho_0, \\ dy_0 &= \sin a_0 \cos \delta_0 \, d\rho_0, \\ dz_0 &= \cos \sin \delta_0 \, d\rho_0.\end{aligned}$$

8. The method may be applied to longer arcs by using closed expressions in place of the series in group VI.

A METHOD OF COMPUTING ORBITS IN RECTANGULAR COORDINATES.

BY A. O. LEUSCHNER.

From

$$\omega a = f a \omega_0 + g a \omega_0 \quad (\omega = x, y, z)$$

(*Publications Lick Observatory,* Vol. VII, part I) the author derives the three fundamental equations:

$$\omega_0 = \frac{g_{\rm III}}{f_{\rm I} g_{\rm III} - f_{\rm III} g_{\rm I}} \omega_{\rm I} - \frac{g_{\rm I}}{f_{\rm I} g_{\rm III} - f_{\rm III} g_{\rm I}} \omega_{\rm III} \cdot$$

Introducing

$$\rho \cos a \cos \delta = x + (X)$$

in the first of these three equations, it becomes

$$\frac{g_{111}}{f_1 g_{111} - f_{111} g_1} p_1 \cos a_1 \cos \delta_1 - \frac{g_{111}}{f_1 g_{111} - f_{111} g_1} p_{111} \cos a_{111} \cos \delta_{111}$$
$$- p_0 \cos a_0 \cos \delta_0 + (X)_0 - g_{111}(X)_1 + g_1(X)_{111} = 0$$

where the (X) (similarly the (Y) and (Z) in the remaining two equations) are the solar coordinates, corrected, to eliminate parallax, by the formulæ given in 3 of the foregoing 'Notes.' These coordinates are referred to the beginning of the year and apply to the actually observed dates.

The solution of the fundamental equations gives at once

$$p_0 = \frac{c_x D' + c_y D'' + c_z D'''}{D}$$

where the *D's* are simple functions of the uncorrected observations, and

$$c_x = (X)_0 - \frac{g_{111}}{f_1 g_{111} - f_{111} g_1} (X)_1 + \frac{g_1}{f_1 g_{111} - f_{111} g_1} (X)_{111}$$

or otherwise

$$c_x = (X)_0 - \frac{[r_{11} r_{111}]}{[r_1 r_{111}]} (X)_1 - \frac{[r_1 r_{11}]}{[r_1 r_{111}]} (X)_{11}$$

and where c_y, c_z are given by similar expressions. If not previously available, a first approximation to the triangular ratios may be obtained by the 'Short Method, etc.' Next ρ_1, ρ_{111}, x_0', y_0', and z_0' are obtained by simple expressions. The accuracy of the initial values of the ratios of the triangles is now tested by recomputing them from closed expressions or by the series. Any disagreement between the initial and final values is removed by means of differential formulæ. The elements are computed by formulæ VIII of the 'Short Method.' The use of rectangular coordinates as outlined in the paper presents many advantages and is applicable to long arcs.

THE SOLUTION OF AN ORBIT IRRESPECTIVE OF PARALLAX AND ABERRATION.

BY A. O. LEUSCHNER.

In the 'Method of Computing Orbits in Rectangular Coordinates' the effects of parallax and aberration are fully eliminated, except in the expressions for the ratios of the triangles, in which the θ's are affected by the difference of planetary aberration (*e. g.*, $\theta_{11} = k(t_{111} - t_1)$). In certain rare cases, particularly for very short intervals, the c_x, c_y, c_z become so small that the solution will become indeterminate unless the accurate differences in planetary aberration can be introduced at the start. In a first orbit, therefore, recourse is had to eliminating the first powers of the differences in aberration, by segregating the first powers of the θ's as factors from c_x, c_y, c_z and then replacing them by expressions involving the differences of aberration, *e. g.*,

$$\theta_1 = \theta_1^0 - k\alpha(\rho_{111} - \rho_1).$$

The fundamental equations then take the form

$$a\rho_1 + b\rho_0 + c\rho_{111} + d + k\alpha e\rho_{111}\rho_1 + k\alpha f\rho_{111}\rho_0 + k\alpha g\rho_0\rho_1 = 0,$$

where α is the aberration factor.

The solution of these equations is reduced to the solution of two equations of the form

$$\rho_0 = f(\rho_{111} - \rho_1) \quad \text{and} \quad \rho_{111} - \rho_1 = \phi(\rho_0)$$

from which $(\rho_{111} - \rho_1)$ and ρ_0 are obtained.

THE ORBIT OF COMET 1902 *a*.

BY A. O. LEUSCHNER.

The paper contains a preliminary report on the investigation of the orbit of comet 1902 *a*. A preliminary orbit based on three observations, of which the third represented a single micrometric measure in α and δ was published shortly after the appearance of the comet. The elements, which were computed by the 'Short Method,' indicated an unusually short period. A comparison of the sum of the squares of the residuals from the elliptic with those from a parabolic orbit computed at Kiel gave the following results for the first nine observations;

Parabolic Orbit,	[vv] = 2985
Elliptic Orbit,	[vv] = 711

For further investigation the observations were grouped into six places, three of which represent single observations, one was based on two, one on three, and one on five observations. The best three of these were selected for the improvement of both the parabolic and elliptic orbits. The final parabolic orbit is completed and does not represent the observations so well as the preliminary elliptic orbit. In determining the final elliptic orbit many difficulties were encountered which led to the theoretical results given in the foregoing papers. The calculation of an orbit irrespective of parallax and aberration has just been undertaken. A preliminary improvement of the orbit gave evidence that the first results concerning a very short period will be substantiated. The following students and assistants have taken part in the computations: Dr. R. T. Crawford; Messrs. H. K. Palmer, Joel Stebbins, Ralph Curtiss, C. A. G. Weymouth, Fellows in the Lick Observatory; and Miss A. M. Hobe.

THE PHOTOHELIOGRAPH OF THE U. S. NAVAL OBSERVATORY; ITS USE AND DEFECTS IN STAR PHOTOGRAPHY.

BY G. H. PETERS.

This paper dealt with the changes made in the instrument during the past four years. A considerable variation of focal length has been found, amounting to about one-half inch, between the temperature of summer and winter. In a proposed new and larger instrument, some defects due to the attached building are to be avoided.

The use of Jena glass No. 0.2164 combined with No. 0.2001, with an alternative of No. 0.164, is suggested for this lens, to reduce the secondary spectrum to a minimum.

Attention was called to the necessity of a study of the thermo-focal changes in long focus lenses, to be used in eclipse work.

RESULTS OF MERIDIAN OBSERVATIONS FOR STELLAR PARALLAX MADE AT THE WASHBURN OBSERVATORY, UNIVERSITY OF WISCONSIN.

BY ALBERT S. FLINT.

Results were presented for a list of ninety-six stars whose distances from the solar system were to be determined. This list consists mainly of stars whose proper motion, or drift across the heavens, is comparatively large; and these results show that, on the average, the larger this apparent motion, the nearer the star. These observations were forwarded to Professor Kapteyn, of Groningen, Holland, who made use of them in an important investigation of the structure of the heavens.

PRELIMINARY STATEMENT OF THE MAGNETIC DISTURBANCES COINCIDENT WITH THE RECENT ERUPTION IN MARTINIQUE.

BY L. A. BAUER.

The disturbances of the magnetic needle coincident with the volcanic eruptions of May 8 and 20 were felt practically simultaneously at the four Coast and Geodetic Survey magnetic observatories situated respectively at Cheltenham (Maryland), Baldwin (Kansas), Sitka (Alaska) and Honolulu (Hawaiian Islands).

In response to a circular sent by the Superintendent of the Coast and Geodetic Survey records have been received from the principal foreign observatories. A cursory examination of these records shows the disturbances and that they occurred practically simultaneously at all of the observatories thus far heard from. An examination of the records indicates that apparently there were premonitory symptoms a month before the actual outbreak. The records will be subjected to a critical discussion, with the view of settling definitely whether the cause of these remarkable disturbances had its source within or outside of the earth's crust.

A comparison of these effects was made with that which had revealed itself during the total solar eclipse of May 28, 1900, and also the more recent one of May 18, 1901. It was shown that the eclipse effect is not in any sense to be classed as a magnetic disturbance, but that it is of the periodic variation kind and is precisely similar in character to the solar diurnal variation.

PRELIMINARY NOTE ON THE TOTAL LIGHT OF THE STARS.

BY SIDNEY D. TOWNLEY.

While engaged in photometric work at the Lick Observatory during the past summer a few experiments were made to determine the amount of light received from the sky at night when the moon is not shining. This work was undertaken at the request of Director Campbell, to whom the problem was suggested by Professor Newcomb.

Both visual and photographic methods are applicable to the solution of this problem, and Professor Newcomb has already employed some of the visual methods, the results of which were printed in the *Astrophysical Journal,* December, 1901. My efforts were directed almost exclusively to perfecting a photographic method.

The results thus obtained are meager, but it is believed that a reliable method has been found.

The method adopted is, indeed, very simple. Both lenses were removed from the Crocker photographic telescope and a cardboard cap of three centimeters diameter attached to the end of the telescope tube. An exposure of one hour was made upon a bright star and the result was, of course, an impression on the plate of the size and shape of the aperture. Exposures were then made upon the sky by means of four camera boxes, consisting simply of aperture and plate, attached to a polar axis made of a piece of 4 x 4. The angular apertures used varied from five to ten degrees. The five plates were developed at the same time in a large tray, and their relative intensities measured by means of a Lummer-Brodhun photometer.

In the very limited length of time which I had to devote to this work it was possible to obtain only a few sets of plates. Two of these sets give reliable results. In each Vega was the comparison star used. In the one the camera boxes were directed to the sky about half way between γ Pegasi and β Ceti, in the other to the Milky Way nearest Vega.

The results are, from the first, that the light of Vega is equivalent in actinic intensity to the light received from an area of rather vacant non-galactic sky $7^\circ\ 16'.4$ in diameter, from the second, that the light of Vega is equivalent to the light received from an area of galactic sky $5^\circ\ 19'.8$ in diameter. This gives galactic sky to be 1.9 times brighter than non-galactic sky. If we take the magnitude of Vega to be 0.2, then from the first result we find that the light received from an area of non-galactic sky one degree in diameter is equal to the light of a 4.5 magnitude star, which is not far from the result obtained by Professor Newcomb, namely, that the light received from an area of non-galactic sky one degree in diameter is equal to 0.9 the light of 5.0 magnitude star.

PHOTOMETRIC AND PHOTOGRAPHIC OBSERVATIONS OF FAINT VARIABLE STARS.

BY J. A. PARKHURST.

In the course of this work at the Yerkes Observatory several stars have been found whose brightness at minimum is at or below the limit of the forty-inch refractor. To illustrate three specimen fields, lantern slides were prepared from negatives taken with the twenty-four-inch reflector, covering a field of 30′ around the variable, corresponding to the inner square of Hagen's charts.

7220 S Cygni.—Plate taken November 24, 1902, exposure 61 minutes The variable is about the eleventh magnitude; its greatest range of variation is from the eighth to the sixteenth magnitude, being approximately equal at maximum to the star 1′ north, and at minimum to the star 0′.5 preceding.

7458 V Delphini.—Plate taken September 7, 1902, exposure 68 minutes. This star has perhaps the greatest range of any known variable. At the maximum of 1899 it reached nearly the seventh magnitude, at minimum it is about the seventeenth magnitude. As shown on the slide it is tenth magnitude, at its faintest it is equal to the small star 0′.2 south.

7582 X Cephei.—Plate taken March 13, 1902, when the variable was photographically fainter than seventeenth magnitude, and visually below the limit of the forty-inch when using the eyepiece of the photometer, power 237. The magnitude at maximum is 9.7, equal to the star 4′ south, 1′ following.

The work in progress includes determination of the photometric magnitudes of comparison stars for 25 faint variables, using the equalizing wedge photometer devised by Professor E. C. Pickering, in connection with telescopes of six, twelve and forty inches aperture; connecting the comparison stars with Harvard and Potsdam standards in the neighborhood; also visual comparisons by Argelander's method, and photographs of the fields for the purpose of certain identification of the comparison stars, and for determining the brightness of the variable when below the visual limit of the telescopes used.

No abstracts are available for the following papers which were also presented at this meeting.

On Certain Matters Concerning Spectroscopic Methods. By W. J. Humphreys.

The Wave-length of Rydberg's First Line of Hydrogen (λ 4686) and Others. By E. B. Frost and W. S. Adams.

Periodic Solutions of the Problem of Four Bodies. By E. O. Lovett.

On the Integrals of the Problem of *n* Bodies. By E. O. Lovett.

The New Gases, Neon, Krypton and Zenon in the Chromosphere. By S. A. Mitchell.

Astronomical Laboratory Work for Large Classes. By Sarah F. Whiting.

The Pressure of Light and its Illustration in the Construction of a Laboratory Comet's Tail. By E. F. Nichols and G. F. Hull.

FIFTH MEETING

The fifth annual meeting of the Astronomical Society was held in the Central High School Building, at St. Louis, Missouri, on Tuesday and Wednesday, December 29 and 30, 1903, in affiliation with the American Association for the Advancement of Science.

The attendance was the smallest of any meeting in the history of the Society, less than twenty members were present. Three sessions were held for the reading and discussion of papers, the first on Tuesday afternoon, the others on Wednesday morning and afternoon. The session on Wednesday morning was a joint one with Section A of the American Association.

On Wednesday afternoon officers were elected as follows:

President	Simon Newcomb
First Vice-President	George E. Hale
Second Vice-President	W. W. Campbell
Treasurer	C. L. Doolittle
Councilors for two years	E. C. Pickering R. S. Woodward

Professors George C. Comstock and W. S. Eichelberger were elected members of the Council of the American Association for the Advancement of Science from the Astronomical and Astrophysical Society of America.

Professor Eichelberger was chosen Editor for the meeting.

ABSTRACTS OF PAPERS

THE D. O. MILLS EXPEDITION.

BY W. W. CAMPBELL.

The observing station of the D. O. Mills expedition from the Lick Observatory to the Southern Hemisphere was completed in October. It is located on the summit of San Cristobal in the northeastern suburbs of Santiago, Chile. Its elevation above the city is about nine hundred and fifty feet, the altitude of Santiago above sea level being eighteen hundred feet. The distance from the center of the city is about two miles.

The expedition is in charge of Acting Astronomer W. H. Wright, who is assisted by Dr. H. K. Palmer.

The unfortunate delays encountered in completing the mirrors for the reflecting telescope made it unavoidable that the expedition should reach Chile at the beginning of the southern winter—the rainy season. San Cristobal was selected as the site early in June. The expedition reached Chile just a few days before the breaking out of very serious labor troubles. This and the storms of winter made the construction of the observatory on the summit one of considerable difficulty. The requirements for erecting the Warner and Swasey steel dome, the reflecting telescope, the electric power line from the valley to the summit, etc., could not be met by skilled labor obtainable in Chile, and the astronomers were called upon the supply this almost entirely themselves.

Up to October 9, 1903, spectrograms had been secured for determining the speeds of twenty stars, and ere this the number is undoubtedly much greater. At the time of writing, photographs of the dome, office building and general surroundings have not been received.

The completion of the extensive installation in the four winter months, in spite of lack of skilled assistance and the frequent interruptions by storms, together with the securing of a considerable number of spectrograms, is sufficient testimony that numerous and valuable results will be secured in the time assigned for the work.

THE SUN'S MOTION RELATIVE TO A GROUP OF FAINT STARS.

BY GEORGE C. COMSTOCK.

A year ago the author presented to this Society a set of proper motions of faint stars (ninth to twelfth magnitude, distributed throughout the twenty-four hours of right ascension) determined from micrometric observations extending over a period of about half a century. During the past year the author derived from these proper motions a determination of the direction and magnitude of the sun's motion, using Airy's method for the formation of the necessary equations. This method requires that some assumption shall be made with regard to the distance of each star employed, and for this purpose the author used an extrapolation of Kapteyn's formula, which represents this distance as a function of the proper motion and stellar magnitude.

The author has thus derived from absolutely new data, no one of the proper motions employed having entered into any previous investigation, the following coordinates of the apex of the solar motion:

R.A. = 297°, Decl. = + 28°.

The mean result of previous determinations from brighter stars is

R.A. = 275°, Decl. = + 30°.

The present solution furnishes as the linear velocity of the sun's motion 4.8 radii of the earth's orbit per annum, which, compared with Campbell's spectroscopic result, 4.2 radii per annum, indicates that the assumed parallaxes of the stars are not greatly in error. Adjusting the assumed distances so that the resulting solar velocity shall agree with the spectroscopic determination, the author finds for the average parallax of sixty-seven stars included between the ninth and twelfth magnitudes, $\pi = 0''.0051$.

This number, sixty-seven stars, represents the entire amount of data at the author's disposal, no proper motion having been rejected in the discussion, but it is doubtless too small a basis for a determination of the elements of the solar motion and, at least provisionally, the author prefers to interpret the results noted above, as evidence that the proper motions obtained for these faint stars are real quantities and that the methods employed for their determination may with advantage receive wider application. The author has now in hand a similar determination of proper motions of all stars fainter than the eighth magnitude for which suitable data can be obtained from the earlier double star observations of the Struves.

PHOTOGRAPHS OF COMET 1903 *c* (BORELLY).

BY SEBASTIAN ALBRECHT.

This paper gave a preliminary account of results obtained from thirty-seven photographs of the comet taken at the Lick Observatory. The photographs show that the comet had two distinct types of tails—one very much curved and short, never much exceeding a degree and a half in length, the other long, and in its general direction straight. Measures of the long tail show that its average lag behind the radius vector was less than two degrees.

The period from the 22d to the 26th of July was one of unusual activity in the comet. The plates of July 23, 24 and 26 show detached portions of the main tail, indicating changes in the emission of cometary matter from the head. From a comparison of the Lick plate of July 24 with two plates of the same date taken at the Yerkes

Observatory and one taken at Nanterre, an average recession from the head of thirty-five miles per second was obtained for a detached section of the main tail. This is equivalent to thirteen miles per second relative to the sun.

The paper was accompanied by slides showing the principal features of the comet.

A more complete account of results has been published in a *Bulletin of the Lick Observatory.*

THE EROS PARALLAX PHOTOGRAPHS AT THE GOODSELL OBSERVATORY.

BY H. C. WILSON.

Some of the results of the measurements of photographs taken with the eight-inch photographic telescope at the Goodsell Observatory were exhibited. A rough solution of the equations derived from the best situated plates gives for the solar parallax 8″.799. Similar equations from the published results from photographs taken at the Bordeaux and Paris Observatories give for the parallax 8″.798 and 8″.794 respectively.

ADDITIONAL PAPERS.

The following additional papers were presented at this meeting, for which abstracts have not been received.

The Prediction of Occulations of Stars by the Moon. By G. W. Hough.

The Absorption of Solar Radiation by the Sun's Atmosphere. By F. W. Very.

The Pivots of the Nine-Inch Transit Circle of the United States Naval Observatory. By W. S. Eichelberger.

A Short Sketch of the Progress of Astronomy in the United States. By M. S. Brennan.

SIXTH MEETING

The sixth meeting of the Astronomical Society was held on Tuesday, Wednesday, Thursday and Friday, December 27-30, 1904, in room 106, College Hall, University of Pennsylvania, at Philadelphia, in affiliation with the American Association for the Advancement of Science. There were three sessions for the reading and discussion of papers and the transaction of business, held on the afternoons of Wednesday, Thursday and Friday. Thirty-six members were present at the meeting, and, including visitors, the average attendance at the sessions was about fifty.

During the meeting a number of members availed themselves of the invitations by Professor Doolittle, Director of the Flower Observatory of the University of Pennsylvania, at Upper Darby, and by Professor Snyder, Director of the Philadelphia Observatory, to visit and inspect the extensive astronomical equipments of these institutions. A pleasant social feature connected with the meeting was an informal dinner on Thursday evening, at Hotel Walton, at which twenty-six members and friends were present.

Officers were elected as follows:

President	Simon Newcomb
First Vice-President	George E. Hale
Second Vice-President	W. W. Campbell
Treasurer	C. L. Doolittle
Councilors for two years	Ormond Stone W. S. Eichelberger

On account of the contemplated absence from the country of Professor Geo. C. Comstock for the greater part of the year 1905, Professor W. S. Eichelberger was appointed Acting Secretary by the Council. Professor Frank B. Littell was chosen Editor for the meeting.

Early in 1904 the National Academy of Sciences appointed a committee to formulate plans for securing international cooperation in solar research. This committee requested the appointment of a similar committee from the Astronomical Society to cooperate with them, and during the summer such committee had been appointed by the President of the Society. At this meeting the Council made this a standing committee of the Society.

ABSTRACTS OF PAPERS

THE CONSTANT OF ABERRATION.

BY C. L. DOOLITTLE.

The systematic observation for variation of latitude was begun by the author December 1, 1889. This work has been kept up with some interruptions since that time. In 1896 was begun at the Flower Observatory a series which it was proposed to continue on a uniform plan for a period of seven years. This design was carried out with but little departure from the original program. Observation on this series was terminated December, 1903.

Work is now in progress on a more comprehensive plan, two instruments being employed, viz., the five and one-half-inch zenith telescope, and the eight-inch Wharton reflex zenith tube.

The close of the former series seems to mark the proper time for bringing together the values of the aberration constant which have been obtained, and for combining them to form a mean which may be considered final so far as may be shown by these observations.

The different values found are as follows:

SAYRE OBSERVATORY, SOUTH BETHLEHEM

DATE	ABERRATION	NO. PAIRS	WEIGHT
1889 Dec. 1—1890 Dec. 13	20″.448 ± .014	1479	0
1892 Oct. 10—1893 Dec. 27	20 .551 .009	2900	1
1894 Jan. 19—1895 May 16	20 .537 .014	1989	1
FLOWER OBSERVATORY, PHILADELPHIA			
1896 Oct. 19—1898 Aug. 16	20″.580 ± .008	2009	1
1898 Oct. 8—1899 Nov. 27	20 .540 .010	1503	2
1900 May 5—1901 Aug. 30	20 .561 .008	1994	2
1901 Oct. 3—1902 Dec. 1	20 .513 .009	1935	2
1903 Jan. 22—1903 Dec. 7	20 .524 .009	1554	2

The reasons which have led to assigning the weight 0 to the first determination will be found fully set forth in connection with the published results of this series, given in the *Transactions of the American Philosophical Society,* Vol. XX, p. 318.

For various reasons which are fully explained elsewhere the first series at the Flower Observatory is not thought to be as reliable as the following ones. It has accordingly been assigned weight 1, the four remaining values being given weight 2. Combining according to these weights, we find for the mean,

$$20''.540 \pm 0''.0055$$

I wish this to be regarded as the definitive value of this constant as derived from the zenith telescope observations extending from December, 1889, to December, 1903.

THE TEST OF A TRANSIT MICROMETER.

BY JOHN F. HAYFORD.

When, in connection with an astronomical transit as used for time observations, a transit micrometer and chronograph are substituted for a system of fixed lines in the diaphragm, a telegraphic key and the chronograph, the observer is relieved of the necessity of operating the key at, or as soon as possible after, each of the several instants of transit of the star across the fixed lines. Instead, he is required simply to keep the star image bisected continuously by the movable micrometer line during its progress across the field of view. In the new process of thought the element of time enters only in an indirect manner. Hence, with a transit micrometer, the personal equation becomes so nearly zero, and its variation so nearly zero, that it is difficult to prove that they are not both absolutely zero. The personal equation is one of the most serious sources of error in all time determinations and determinations of right ascension. The destiny of the transit micrometer is to produce a decided increase in accuracy in this class of observations without increase of effort or cost.

The observation of star transits by means of a movable transit line was first suggested in 1865 by Director Carl Braun of the Kalocsa Observatory. He believed that it was necessary to have the movable line driven by clockwork. He failed to construct a satisfactory apparatus.

Repsold, the well-known instrument maker, was the first to suggest in print, in 1889, that no clockwork is required. He constructed a hand-driven transit micrometer with which excellent results were secured.

The Prussian Goedetic Institute put the Repsold hand-driven transit micrometer into use on portable instruments in making telegraphic longitude determinations in 1891, and has continued its use to the present time. In all, it has been used in ten longitude determinations.

Utilizing the published past experience with transit micrometers Mr. E. G. Fischer, Chief of the Instrument Division, Coast and Goedetic Survey, designed and constructed in the winter of 1903-4 the transit micrometer which is before you, and which is adapted for use on the transits ordinarily used in longitude determinations. It is a hand-driven transit micrometer.

It is so well designed and constructed that in the extensive tests, to which I shall refer in a moment, it never required the slightest change in adjustment, not even of the pressure of the contact spring, and not a single record was ever lost on account of any failure of the transit micrometer to operate properly.

A peculiar and important feature of this transit micrometer is an automatic switch which operates, without the slightest attention from the observer, in such a manner that a record is made on the chronograph for the middle four turns of the field, and for those turns only. This positively identifies those four turns, keeps the chronograph sheet clear, and enables the observer to practice following the star during the earlier part of its transit without affecting the chronograph sheet in any way.

In March, April and May, 1904, this instrument was tested by seventy-five time sets on eighteen nights at the Coast and Geodetic Survey office. Sixteen observers took part in this test. The observers were purposely selected so as to include some with little or no experience in any kind of observation, some with long experience in astronomical observations and in handling various instruments of precision, and some of various grades between these two extremes. Two observers worked at the same time, observing alternate stars, and thus obtaining a determination of their relative personal equation. One of the sixteen observers was in the test continuously, and became thoroughly accustomed to the instrument and method of observation, and served as an intermediary through whom all the other observers could be compared with each other.

The tests show that for a practiced observer with such a transit micrometer, the total error for a star, including errors which are constant for all the records as well as the accidental errors of bisection, is nearly the same for stars of all declinations if expressed in angular magnitude. This is what should be expected if the errors concerned are of the same nature as if the object pointed upon were stationary instead of moving.

The accidental errors of bisection are nearly the same expressed in angular magnitude for stars of all declinations up to 59°. and are probably somewhat less for stars of greater declination. This is an indication that the accidental errors of bisection are of the same nature as if the image pointed upon were stationary, the indication being partly contradicted by the smaller errors for stars of declination greater than 58°.

Good observations can be secured at once with the transit micrometer without previous practice. Practice simply reduces the accidental errors by about 25 per cent. I feel that I may speak with assurance on this topic, for each of the sixteen observers was forced to begin observing on the first star that appeared on his field of view, with no previous experience whatever. This point is emphasized for the reason that I had been led to expect that long practice would be necessary before an observer could be sent to the field with a transit micrometer. The accidental error of a single record with the transit micrometer is about the same as that of a single record with a key.

During the first half of the tests the driving heads were geared to make one turn in $2^s.4$, when observing an equatorial star. During the last half of the tests the driving heads were geared to turn one half as fast, namely, one turn in $4^s.8$. This extreme change in speed produced surprisingly little effect on the accuracy of the results. With this instument the speed of $4^s.8$ per turn, or possibly a slightly slower speed, is believed to be most favorable to accuracy.

The tests show that the relative personal equation between any two observers with the transit micrometer is so small as to be masked by the accidental errors of observation. This is equivalent to saying that it is probably less in every case than $0^s.05$, and is, as a rule, much smaller than this. The relative personal equation with a transit micrometer is certainly not more than one tenth as large, upon the average, as with a key. This conclusion as to the relative personal equation applies to inexperienced as well as to experienced observers.

The literature of the transit micrometer shows abundant corroboration of these conclusions as to the relative personal equation.

It is difficult to detect constant or systematic errors of any kind in transit micrometer observations. All the errors seem to belong to the accidental class. This is far from being true of key observations.

The transit micrometer is about to be put into use in the regular longitude work of the Coast and Geodetic Survey.

I predict, basing my prediction upon the general experience with transit micrometers as well as on these particular tests, that with a transit micrometer three nights of observations without exchange of observers will give as great accuracy as has been secured in the past from ten nights of observations with a key, including an exchange of observers. This is a prediction of which the truth or falsity can only be proved conclusively by field experience. I rely upon such experience to be gained within the next five years to verify the prediction.

I venture to predict also that the evidence in favor of the transit micrometer will accumulate to such an extent in the next ten years in fixed observatories, as well as with portable instruments, that the astronomer who uses a key in 1914 for accurate time determinations or determinations of right ascension will have difficulty in furnishing adequate explanation of his conduct.

An illustrated description of the Coast and Geodetic Survey transit micrometer, with a full report of the tests referred to above, and a brief résumé of a part of the literature of the transit micrometer is now being printed as an appendix to the *Coast and Geodetic Survey Report* for 1904.

REMEASUREMENT OF THE HOUGH DOUBLE STARS.

BY ERIC DOOLITTLE.

The catalogues of new double stars published by Professor Hough comprise six hundred and twenty-two pairs, of which seventy-seven are closer than half a second, one hundred and forty-three closer than one second; in those pairs in which the distance is greater than five seconds the companion is usually excessively faint; in fact, there are few of the stars which would not be difficult with a telescope of much less than eighteen inches aperture.

The measurement of this fine series of doubles seems to have been strangely neglected. On a few of them, which are of the type of close pairs of equal magnitudes, as Ho. 98, Ho. 260, and Ho. 296, there are a number of rather discordant measures, but the great majority have received no attention except from the discoverer himself. Thus there are but eighty-seven pairs which have been measured in two different years, and on no less than three hundred and fifty-eight there is but a single prior measure.

The entire list was, therefore, added to the observing list for the eighteen-inch refractor of the Flower Observatory. Thus far, three hundred and sixty pairs have been measured on three or more nights and many of the remaining two hundred and sixty-two are partially measured. A single night's measure consists in each case of at least four measures of position angle and four of the double distance.

Change has been found in sixteen of the close pairs, and among the wider ones there is in thirty-three instances indication of proper motion.

It is the intention, when the work is completed, to publish a catalogue of these stars, including about twenty new pairs which Professor Hough has discovered since the last list was issued.

A STUDY OF THE DRIVING-WORMS OF SEVERAL PHOTOGRAPHIC TELESCOPES.

BY EDWARD S. KING.

In following a star with a photographic telescope we must have for the period of the exposure a clock the hour hand of which will indicate the elapsed time on a scale graduated to seconds or less. We must have the equivalent of being able to determine the time by measuring the position of the hour hand with a micrometer. If any periodic error occurs in the train of the driving mechanism, causing the telescope to be first in advance of, and then behind, its proper position, the stellar images will be elongated into lines having a length dependent upon the amount of the oscillation. If the telescope follows the star only at one extremity of the oscillation, we shall have a series of images separated by trails, or, if the rate of the telescope is changed more, we shall have a trail with dark knots appearing at regular intervals. The number of the knots determines the frequency of the oscillation, and almost invariably indicates the driving worm or endless screw as the offending member.

Such a periodic error, as shown by slide 1, is present in nearly all telescopes driven in this manner. This fact is not new, but has been recognized for years. The first example that I know of personally occurred in 1888 with the Boyden thirteen-inch telescope. In 1896 the director asked me to determine the periodic error of two of our photographic telescopes. Several series of measures were made of the eight-inch and the eleven-inch Draper telescopes. The method was to view a point of the tail-piece through a fixed microscope fitted with a micrometer. After each release of the detent by means of the signals given by hand, the position of the point was read and recorded. The reduction of these measures shows that the oscillation for the eight-inch Draper telescope was about one second, and for the eleven-inch Draper telescope about two tenths of a second. These figures correspond to trails of less than 0.01 cm. on the plate. Within a few years Dr. Hartmann has studied the periodic error of the Potsdam refractor and provided a very ingenious method of correction. A full account of his work will be found in the *Astronomische Nachrichten,* No. 3769.

Nothing further was done here until the present year, when one of the small cameras was provided with a new mounting. The images proved to be lines lying in the direction of the clock's motion, and might, therefore, be affected by a periodic error. I proceeded to investigate the difficulty by a photographic method. The polar axis of the instrument was displaced in azimuth by a large amount. Such a displacement would cause equatorial stars, particularly when near the meridian, to move over the plate in declination. If an oscillation occurred, it would appear in the sinuous character of the trail. Slide 2, which is enlarged ten times from the original plate, shows the result, permitting no doubt as to the nature of the error. The numerous elongated objects are images of stars obtained on the same plate in the ordinary way. It is seen that the elongation of the images corresponds to the amplitude of the oscillation as exhibited by the vertical trail. The number of the oscillations was fifteen per hour, which fixes the responsibility upon the worm. A similar experiment made with a worm which had given satisfactory images is shown in slide 3. A slight irregularity is seen, but does not prove injurious. The same experiment made with the eleven-inch Draper telescope did not show anything definite, due probably to the smallness of the error. It is possible that it could be brought out by attaching an enlarging apparatus to the instrument and this will be tried soon.

The defective worm and several others were also tested visually. A telescope of about four feet focal length and having an eye-piece provided with a cross wire, was lashed to the camera and directed to a scale graduated to millimeters and placed at a distance. I was thus able to record the position of the telescope accurately. After every ten beats given by hand to the driving mechanism, the position was read for a period covering more than a revolution of the worm, which occurred in 240 seconds. The readings at the beginning and the end of the revolution determined the average rate from which were found the positions which the telescope should have occupied for the intermediate times. A comparison with the observed positions gave the periodic error. It was possible for the worm to be defective either in the thread itself or in the mounting. Rowland makes the remark that the correct mounting of a screw is more difficult than making the screw. It seemed to be so in the present case. If the screw was mounted eccentrically, we might expect a great improvement if it were allowed to engage only lightly with the right ascension wheel, being held in position by a strong spring. Slide 4 exhibits the resulting curves. It is seen that when the worm was adjusted to engage only lightly with the right ascension wheel, the oscillation extended through nearly eight seconds, but that, when brought into contact, the range was hardly two seconds. Thus the error of this particular worm was eccentricity.

A further test was made to determine if any intermediate adjustment of the worm with respect to the right ascension wheel would be advantageous. Slide 5 gives a set of curves for the various settings, beginning with the position in contact and ending with the worm very lightly engaged. Curve 1 is best and curve 3 is worst. That the position in contact is not always best is shown by slide 6, giving results for the worm that proved satisfactory. In this case the action was quite erratic when the worm was in contact.

A further test was made of the eleven-inch Draper telescope to determine the best adjustment of the worm with respect to the right ascension or sector wheel. Slide 1, which has already been seen, shows the appearance of the trails at what may be considered an average adjustment. In slide 8 we have the result when the worm is in contact, and in slide 9 when the position is adjusted to give the least error, found by trial. Probably in all instruments, one may, without any process of reconstruction, find by experiment where the periodic error is much decreased.

The foregoing has been in the nature of an abstract of an investigation in progress rather than a detailed account of work complete. It is possible that a careful study of curves representative of the action of the driving worm will suggest an improvement in cutting the thread. As the experiments are easily made, I hope that other observers will test their instruments. A comparison of the results obtained with a greater variety of instruments would be of interest and might lead to a better understanding of the entire subject.

THE REFLEX ZENITH TUBE.

BY C. L. DOOLITTLE.

In 1851, or thereabout, the instrument having this designation was installed at Greenwich. The maker was Mr. Simons, the designer Mr. J. B. Airy. The immediate object in view was the observation of γ Draconis, a star which has been followed at Greenwich with some kind of zenith instrument since the time of Bradley.

The principle is briefly as follows: The telescope is fixed permanently, with its axis vertical as nearly as may be. Below the objective at a distance nearly half that of the focal length is placed a basin of mercury. The rays from a star at the zenith after passing through the objective, are reflected from the mercury surface and brought to a focus immediately in front of this objective. By means of a micrometer, the frame of which is firmly attached to the cell of the objective, with the plane of the reticle passing through the focus, the zenith distance of a star culminating within ten or fifteen minutes of the zenith may be measured. Finally a diagonal reflector brings the ray to the ocular, which is at right angles to the axis of the objective.

In practice the observation is made by bisecting the star, then quickly reversing by turning the objective with the micrometer attached through 180°, then making a second bisection. One-half the difference of the micrometer readings will evidently be the measure of the star's zenith distance. Obviously both bisections cannot be made with the star on the meridian. This makes necessary a small correction easily determined.

An instrument involving these principles has recently been installed at the Flower Observatory. So far as I am aware this is the second to be constructed. In detail, it differs in a number of particulars from the Greenwich instrument. The optical parts are by Brashear and the instrumental parts by Warner and Swasey. The aperture of the objective is eight inches, the focal length one hundred inches. In the Greenwich instrument this cone of light after reflection passes a second time through the glass of the objective. In this case a hole one and one-half inches in diameter is bored through the objective; through this hole a short tube passes, attached above to the micrometer box. When not in use this tube is closed by a shutter which presses up against its lower end, thus protecting the reticle from dust and moisture as completely as in the ordinary form of telescope. The construction may be likened to that of an ordinary telescope with the tube cut in two near the ocular, this end being passed through a hole through the middle of the objective.

Another matter of importance is this. It is evident that unless the plane of the reticle passes through one of the principal points of the objective, any change in the inclination of the apparatus will shift the zero point of the micrometer with respect to the vertical. This makes necessary a correction depending on the level readings—the very thing which we wish to avoid. For this purpose Dr. Hastings, who computed the curves of this objective, so designed it as to bring the first principal point in front of the upper surface, 0.155 inch. It was a simple matter to place the plane of the reticle at this same distance. These peculiarities introduced into the problem some technical and mechanical difficulties, all of which were successfully overcome, the optical performance being entirely satisfactory.

A solid cast-iron pillar, weighing several hundred pounds, formed the tube of the telescope. The focal adjustment is made by raising or lowering the mercury surface, this arrangement offering no difficulties.

As is usually the case with a new design, in part experimental, various unforseen delays have occurred. All previous difficulties have apparently been overcome, and regular observations are now in progress. At present, observations are carried on simultaneously with this instrument and the zenith telescope; four groups are employed as heretofore. In this program, each group contains eight zenith stars to be observed with the reflex tube, and ten latitude pairs for the zenith telescope, with one wide pair for temperature investigation; the time required for these nineteen observations being on the average approximately two and one-half hours. It is hoped that in the course of two or three years these observations may furnish data tending to throw light on a number of obscure problems.

The star γ Cygni, magnitude 2.5, culminates within less than one minute of the zenith of the instrument. Although at present it differs in right ascension from the sun by only $1^h 30^m$, it is an easy object to observe. There will be no difficulty in following it during the greater part of the year. As an indication of the performance of the instrument the latitudes resulting from a preliminary reduction of the observations made on this star are here given.

1904, **December**	6	$\varphi = 39° 58$ 1″.83
	7	1 .95
	8	1 .85
	9	1 .86
	13	1 .81
	14	1 .79
	16	1 .84
	18	1 .92
	31	1 .79
1905, **January**	1	2 .00

VARIATIONS OF THE BRIGHT HYDROGEN LINES IN STELLAR SPECTRA.

BY ANNIE J. CANNON.

Stars whose spectra are of the Orion type, having also one or more bright hydrogen lines, form a most interesting and peculiar class whose position in the scheme of stellar evolution is enigmatical. The Harvard photographs show that the bright hydrogen lines are variables in the following six of these stars: η Centauri, κ' Apodis, υ Sagittarii, ϵ Capricorni, J Velorum, and 27 Canis Majoris. So far as we know, no variation in the light of any of these stars has ever been observed, although the changes in their spectra point either to great atmospheric upheavals, or to movements of two or more revolving bodies.

The most important changes in the spectrum of η Centauri may be summarized as follows: In 1897 all lines were dark and $H\beta$ was nearly as intense as $H\gamma$. In 1898 and 1899 $H\beta$ was very faint and appeared as a dark line superposed on a faint bright band. In 1901 a most striking change had taken place, for $H\beta$ had become a strong bright line, having considerable shift towards the violet when compared with the dark $H\beta$ present in 1897. $H\gamma$ was dark with a bright band towards the violet. Photographs taken in 1902 recorded the reappearance of the dark line on the edge of greater wave-length of bright $H\beta$, and both lines were of moderate intensity. In 1903 the spectrum was similar to that of 1898. The period of these changes is probably several years in length.

The changes in the spectrum of κ' Apodis are somewhat similar to those of η Centauri. It appears that both these stars are spectroscopic binaries, one component of each being a bright line star. The spectrum of υ Sagittarii presents another difficult spectroscopic problem, perhaps on the order of β Lyrae. The spectrum of υ Sagittarii always appears to be composite. The principal lines seem to be due to two bodies, one having a spectrum like β Orionis and the other like ϵ Aurigae. The spectrum of β Orionis was strongly predominant on seven photographs, but frequently the two spectra seem to be equally intermingled. Perhaps the most curious phenomenon is that on twenty-three photographs, on which the helium lines were very strong, those of hydrogen were unusually weak. $H\beta$ was invisible, appearing neither as a line of emission nor of absorption, while the line at λ 4922 was clearly seen. $H\gamma$ and $H\delta$ were respectively much less intense than the adjacent helium lines at λ 4387.8 and λ 4120.5. It is possible that a third body, having bright hydrogen lines, might explain these appearances.

Eleven photographs of the spectrum of ϵ Capricorni, taken in 1903, showed $H\beta$ to be a faint but distinct bright line lying on the edge of greater wave-length of an equally faint dark line. On earlier photographs, $H\beta$ was dark and of varying intensity. Some faint lines, including several due to iron, are also subject to change in this spectrum.

It is possible that varying atmospheric conditions may account for the changes in the spectra of J Velorum and 27 Canis Majoris. On June 2, 1893, the dark $H\beta$ and $H\gamma$ in J Velorum had a fine bright line superposed. In the spectrum of 27 Canis Majoris, bright hydrogen was present in March, 1890, April, 1895, and October, 1897.

Numerous photographs of both these spectra on other dates showed all the lines to be wholly dark.

It is evident that a large field of investigation lies open to the spectroscopist among these bright-line stars.

VARIABLE STARS IN LARGE NEBULOUS REGIONS.

BY HENRIETTA S. LEAVITT.

Since last March a special study of the distribution of groups of variable stars has been in progress at the Harvard College Observatory. As one result of this investigation, four hundred and fourteen new variables have been discovered and announced. Seventy-three of these are in Orion, one hundred and fifty-two in the Large Magellanic Cloud, fifty-seven in the Small Magellanic Cloud, one hundred and five in Scorpius, ten in Carina, and seventeen in Sagittarius. The results of this study up to the present time may be summarized as follows:

First, as regards distribution, it has become evident that groups of variable stars are strongly localized. Of the ninety-nine confirmed variables at present known in the constellation of Orion, south of the equator, eighty-nine are within the limits of Bond's map of the region surrounding the Nebula of Orion, and of these, all but four are found within less than half this area. The entire region thus finally limited is nebulous. The large number of variables discovered in the two Magellanic Clouds is in marked contrast with the small number found in the surrounding regions. The neighborhood of the Trifid Nebula in Sagittarius is noticeably poor in variable stars, and so also is the neighborhood of the nebula about η Carinae. Yet these are two of the most densely crowded regions of the Milky Way. In Scorpius, after subtracting thirty-three variables which were found in the cluster Messier 4, there are still left more than four times as many variables as were found in an area in Sagittarius approximately equal in extent and far richer in stars.

Secondly, a certain order of brightness appears, on the whole, to prevail among the variable stars of each group, those in the central condensation of the Large Magellanic Cloud being the faintest, and those in Scorpius the brightest.

Finally, it is probable that different types of variability prevail in different regions. In both of the Magellanic Clouds, a large proportion of the variables appear to have very short periods, while in Scorpius, the reverse may prove to be the case. Many of the variables in the Nebula of Orion remain faint during the greater part of the time, but occasionally show a striking increase of brightness. Whether these flashes of brilliancy occur regularly is not yet known.

The researches here described supplement the remarkable discovery of Professor Bailey, of large numbers of variable stars in clusters. They are similar to those carried on by Professor Wolf of Heidelberg, who has announced lists of new variables in Orion, Aquila, and Vulpecula. Evidently a further study of the distribution of groups of variable stars will be intensely interesting in its bearing upon the problems of stellar evolution.

PLANETARY SPECTROGRAMS.

BY PERCIVAL LOWELL.

These spectrograms were made by Mr. V. M. Slipher and the lantern slides of them by Mr. C. O. Lampland, both of the Lowell Observatory staff, and were presented by the director, Professor Lowell.

1. Solar spectrum, photographed November 30, 1903. Fifty-nine dark lines can easily be counted between *G* and $H\gamma$.

2. Spectrum of ϵ Pegasi, photographed September 20, 1904; exposure $2^h\ 15^m$. Iron and chromium comparison spectrum. About fifty-nine dark lines can be counted between G and $H\gamma$.

3. Spectrum of Venus, photographed March 9, 1903. Iron comparison spectrum. This is one of the set from which Mr. Slipher determined the rotation of the planet not to be of twenty-four hours or thereabouts, but very long.

4. Spectrum of Mars, photographed March 7, 1903. Iron comparison spectrum. One of the plates of the set made on Mars by Mr. Slipher to test the measure of precision of the Venus set. The Mars plates gave $25^h\ 10^m \pm$ for the planet's rotation. The true value is $24^h\ 37^m$. As the precision possible on Mars is only about half that possible for Venus the results speak for the decisiveness of the Venus set.

5. Spectrum of Jupiter, photographed November 21, 1903. Iron comparison spectrum. The tilt of the lines shows a rotation in $9^h\ 50^m \pm$, which is exactly the true rotation period as determined by spots.

6. Spectrum of Saturn, ball and rings, photographed September 7, 1904, on a Cramer "crown" plate. Iron comparison spectrum. The tilt of the lines of the ball in one direction and that of the lines of the rings in the other are well shown, demonstrating that the rings are formed of discrete particles, as proved mathematically by

Peirce in part and Clerk-Maxwell in whole and first shown spectroscopically by Keeler.

The spectroscope used in these researches was constructed by Brashear as powerful as possible, especially for the determination spectroscopically of the rotation period of Venus.

THE CANALS OF MARS. AN INVESTIGATION OF THEIR OBJECTIVITY.

BY PERCIVAL LOWELL.

A new and striking proof of the objectivity of the double canals of Mars has recently come to me in a comparison of the width of the doubles obtained by Schiaparelli in 1888 and by me in 1903. The unintentional character of the corroboration is one of its strongest points. Not only at the time of my observations was his work not in my mind, but not even after the fact had I proposed to compare it.

The following table summarizes the results obtained in 1888 and in the May-June presentation of 1903.

CANALS DRAWN DOUBLE BY SCHIAPARELLI, 1888.

	Times Seen.	Width.
Euphrates	4	5°.1
Phison	4	3 .9
Astaboras	3	2 .9
Protonilus	4	2 .2
Pierus	4	2 .4

Canals drawn single by Schiaparelli: Astusapes, Python, Xenius, Rhysius, Apis, Typhon, Hiddekel, Callirrhoe, Deuteronilus.

Two canals, Arnon and Kison, were drawn convergent to the north.

CANALS DRAWN DOUBLE BY LOWELL, 1903.

	Times Seen.	Width.
Euphrates	11	4°.0
Phison	12	3 .7
Astaboras	9	3 .2
Protonilus	8	2 .8
Pierus	2	2 .1
Sitacus (faint)	12	3 .6

Canals drawn single by Lowell: Astusapes, Python, Rhysius, Aroeris, Cadmus, Ægyptus. Hiddekel generally single, Callirrhoe generally a broad line.

Arnon sometimes convergent to the north, sometimes double. Kison suspicious of convergence to the north. For both observers the direction of the canal had nothing to do with its single or double appearance. The conspicuous doubles are the same in the drawings of both observers.

The conspicuous singles are the same in the drawings of both observers. The Arnon and Kison are convergent in both and in the same direction. Only the faint or very close doubles show differences at the two presentations.

The double canals, then, declare their own objectivity on three counts, each more compelling than the one before: (1) The fact of showing double, (2) the relative width of the double, (3) the absolute width of the double; and they do this precisely as a real object would, the certainty increasing with the ease of observation. The determination of the absolute width is very difficult, and here we find the probability for reality strong but not expressible; the relative width is easier to determine and the probability for reality is 24 to 1; lastly the determination of the fact of being double, the easiest observation of all, shows the probability that it is real to be 128 to 1.

NOTE ON THREE SOLAR PERIODS.

BY FRANK H. BIGELOW.

The mean period of rotation of the solar photosphere at the equator is about 26.68 days, as determined by solar observations. There is a mean period of about 25.98 days indicated by terrestrial magnetic and meteorological observations, which has been regarded as a period of solar rotation. The relative frequency of the solar prominences and the annual variations in the earth's atmosphere show that there is a short cycle of about 1004 days. These are apparently related together by the equation,

$$\frac{1}{26.68} + \frac{1}{1004} = \frac{1}{25.98} \text{ (approximately).}$$

Some discussion is given of a possible physical cause for this condition, as found in the interior circulation of the sun's mass.

THE COORDINATION OF VISUAL AND PHOTOGRAPHIC STAR MAGNITUDES.

BY JOHN A. PARKHURST.

The importance of stellar photometry among the departments of modern astronomy arises from the fact that the magnitude of a star bears immediately on the star's physical condition and changes. That this is of growing importance is witnessed, among other things, by the numerous discoveries of new variable stars, over three hundred in the present year; showing that variability must be reckoned with as a factor in stellar evolution to an extent that would not have been imagined a decade ago. The relation lately shown to exist between stellar variability and sunspot phenomena adds at once to the interest of the problem and the possibility of its solution.

The photometric catalogues published within the last few years by the Harvard and Potsdam Observatories furnish a secure basis for visual photometry, their results agreeing reasonably well except the discordances arising from differences in the star colors. No such basis for photographic magnitudes now exists; therefore, to be useful and intelligible, magnitudes must be reduced or reducible to the visual system. But the extension of photometric work demanded by the present needs of astronomy is possible only by photographic means; hence the pressing need of finding some method of harmonizing visual and photographic results for stars differing in type of spectrum and, therefore, in color. The usefulness of such a method will vary somewhat in proportion as it enables us to utilize the photographic magnitudes already obtained.

That the great accuracy of photographic methods applied to the astronomy of position has as yet no counterpart in the astronomy of magnitudes, is due to the one disturbing factor of star color. It is well known that a colored star will affect differently the eye and the photographic plate, but it is not so well appreciated that equal differences arise in the visual estimates of colored stars by different observers or by the use of telescopes of different apertures. The "color correction" amounting to one or two magnitudes for a red star in the photograph, is no greater than the difference between the simultaneous Harvard and Rousdon visual estimates of the brightness of such stars. In fact, we find discrepancies of the same kind and similar in amount between different observers, different telescopes, visual and photographic results, and different brands of plates in photography. If the statement is made that no known relation exists between visual and photographic magnitudes, the retort can be made that a normal visual scale does not exist.

The advantages arising from the use of orthochromatic plates have long been recognized, but Scheiner dismisses them with the statement that they can never yield visual magnitudes. The suggestion was first (as far as I am aware) made by Schwarzschild that the difference between the magnitudes of a colored star on ordinary and orthochromatic plates can be taken as a measure of the star's color. If this difference is a function of the color it only remains to find the form of the function, and then complete allowance can be made for the effect of color and that troublesome factor can be eliminated, making possible the reduction of photographic magnitudes to visual, or *vice versa.* Two methods are available for finding the form of the function. First, by trial on known stars of different color (spectral type). To fix our ideas, suppose, for example, that a star of color 5 on Chandler's decimal scale was 7.0 magnitude visually, but photographed 8.0 magnitude on an orthochromatic plate and 9.0 magnitude on an ordinary plate. For such a star the orthochromatic plate gives half the color correction. It is evident that by such experiments with standard stars of known magnitude and color, the form of the function can be found. This work is being done by the writer, under a grant from the Carnegie Institution, using Cramer isochromatic plates in connection with ordinary plates, on the 24-inch reflecting telescope of the Yerkes Observatory. Provisional results thus far obtained are very promising. An independent method which will also be used for finding the form of the function, consists in comparing the intensity curves of the spectra of stars of different types with the intensity curves of the solar spectrum on the two kinds of plates used. It is evident that the photographic effect is the integral of the product of these two curves.

If the objection is urged that the difficulty of coordinating the results obtained with different brands of ordinary and orthochromatic plates, will be equal to the difficulty of harmonizing the visual and photographic systems, it may be met by the suggestion that any brands of plates used should be calibrated by observations of a carefully selected list of standard stars, including each spectral type.

No less important than the choice of plates is the kind of telescope to be used. It seems to the writer that the reflector is the only telescope suited for this work, since by it the rays of all wave-lengths are brought to the same focus.

Emphasis is needed on two further points in regard to the adaptability of the reflector to this work. When extreme ratios of aperture to focal length are avoided, first, the field is very nearly flat; second, the action is very rapid, so that the work can be extended to faint stars. This flatness of field has been denied, both from theoretical reasons and from so-called measures of reflector plates; but it should be stated that the theory is incomplete, not taking proper account of the distribution of light in the "blurred" image; also that the measures published by Plummer and Poor were not made on the original negatives, and cannot, therefore, be properly called measures. The only real measures so far published, to my knowledge, have been those of the Eros plates taken with the Crossley reflector, and measured at the Columbia University and Lick Observatories. A few of these measures discussed by Hinks showed distortions giving anomalous results near the edge of the plate, but these anomalies are matched on the plates taken at Algiers with the standard photographic refractor, and noticed on the following page of Hinks's paper. It should be stated that the aperture ratio of the Crossley was large, about 1 to 6.

For this work a diaphragm twelve inches in diameter has been used on the twenty-four-inch reflector, and as the focal length is 93 inches, the ratio is a little greater than 1 to 8. Allowing for the area cut out by the flat, the clear aperture of the mirror is equivalent to 10½ inches. The exposures have been timed to give good measurable images of all the stars on Hagen's charts which extend to twelfth or thirteenth magnitude; in good seeing this requires ten minutes with ordinary plates and fifteen minutes on the isochromatic plates. The magnitudes have been deduced by measurements of disk diameters, the increase per magnitude being nearly uniform and amounting to about 0.025 mm. As the diameters are measurable with a probable error of 0.001 mm., corresponding to 0.04 of a magnitude, the results are comparable with the best visual measures.

This work has some similarity to the spectral photometry of the *Draper Catalogue,* each taking account of the intensity curve of the spectrum; but differs from it in two respects: It is not confined to the bright stars, but can reach to the faintest visible; also, taking account of the entire spectrum, its results will harmonize with visual magnitudes.

THE QUADRUPLE SYSTEM OF ALPHA GEMINORUM.

BY HEBER D. CURTIS.

The well-known binary star, α Geminorum was pronounced by Sir John Herschel to be the largest and finest of the double stars in the northern portion of the sky. Measures, of a very rude character, were made of this pair as early as 1718 by Bradley and Pond, so that this system has been under observation for nearly two hundred years. In spite of this fact some of the elements of the orbit are still quite uncertain, particularly the eccentricity and the period. Values of the eccentricity have been derived, ranging from 0.32 to 0.80, with corresponding periods of 1001 to 232 years. In recent years the distance between the two components has commenced to decrease, with the result that the elements have become rather more determinate, and Doberck (*Astronomische Nachrichten,* 3970) has recently expressed the hope that through this decrease in the distance it will be possible to fix the orbit with considerable accuracy within the next ten or twenty years.

Doberck has derived the following sets of elements, of which he regards the second as the most probable and most in agreement with recent measures.

ELEMENTS OF CASTOR.

Ω	=	29° 29′	33° 56′	42° 34′
λ	=	84 44	82 26	118 11
i	=	73 3	63 37	61 56
e	=	0.7513	0.4409	0.2321
Period	=	268 years	347 years	502 years
T	=	1936.65	1969.82	1963.30
a	=	7″.326	5″.756	6″.467

Retrograde.

In January, 1896, Belopolsky at Pulkova discovered that the fainter of the two stars forming this system is itself a rapid spectroscopic binary.* The period of this component is very well determined, being close to 2.934 days. Belopolsky finds, however, certain irregularities in the observations of successive years which are best explained by the assumption that the line of apsides rotates in about fourteen hundred days.

Recent spectrograms taken with the remounted Mills spectrograph show that the brighter component is also a spectroscopic binary, and that the system of α Geminorum is in reality a quadruple one. Since the discovery of this interesting fact in November of this year a number of plates of both stars have been secured. At present fourteen plates are available for a rough preliminary determination of the period, which seems to be about twenty-seven days. Two early plates of the bright component are rather poor, so that their value in determining the period is somewhat impaired and more plates will be necessary before a more accurate determination of the period can be derived.

Both stars are given in the *Draper Catalogue* as of type A, and in

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***Bull. Acad. St. Petersburg,* December, 1896. *Astrophysical Journal,* January, 1897. *Mem. Acad. St. Petersburg,* XI, 4, January, 1900.

the later Harvard classification as type VIIIa. $H\gamma$ is rather broad and has not been used in the measures. The line at λ 4481 due to magnesium is very good and there are quite a number of other metallic lines, rather broad and quite faint in the spectrum of the brighter component, and somewhat easier of measurement in the fainter. Helium is apparently absent. There are a number of lines due to titanium and iron, most of the latter being enhanced lines; two lines seem to be due to chromium. With proper exposure (about sixteen minutes) from fifteen to twenty-five measurable lines are found. The total range in radial velocity is about twenty-one kilometers, and the preliminary determination of the velocity of the center of mass of the system is approximately + 5 km. per second. The corresponding constant for the fainter component is given by Belopolsky in his latest paper as — 4.1 km. per second. It is well known that where the elements of the visual orbit of a binary and the relative radial velocities of its components are both known it is possible to derive an accurate value of its parallax. Assuming the relative radial velocity to be nine kilometers and using the period of 347 years and the corresponding elements which Doberck regards as the most probable, we find a parallax of 0″.03. Using the other orbits given above, however, we should get values differing widely from this. It is evident that such results are meaningless till the elements of the visual orbit are known more definitely.

In the star α Geminorum we have a well established quadruple system, and it is hoped that the more detailed investigation which the writer has in progress will give a definite determination of the relative radial velocity of the two systems, so that with the improvement of the visual orbit we may in time have a relatively very exact knowledge of the distance, mass and orbital dimensions of this complex star.

USE OF THE METHOD OF LEAST SQUARES TO DECIDE BETWEEN CONFLICTING HYPOTHESES.

BY HAROLD JACOBY.

In 1901 the writer published in the *Astronomical Journal*, No. 514, a theorem concerning the application of least squares when it is necessary to choose between two different methods of reducing observations. The theorem was doubtless well known, but the writer was unable to find it in print. Since then, Mr. Midzuhara, of the Tokyo Astronomical Observatory has written three interesting articles, printed in the *Astronomical Journal*, Nos. 521, 535, and 568. In these articles, among other things, he gives a different proof of the writer's theorem, and also obtains another analogous one. The object of the present note is to point out a very important divergence between Mr. Midzuhara's conclusions and the writer's; and also to show how one of the former's most interesting results can be obtained in a manner different from that used by him.

The writer's theorem is: "Let there be given two series of observation equations as follows:

$$\begin{array}{l} a_1 x + b_1 y + c_1 z + \dots + n_1 = 0, \\ a_2 x + b_2 y + c_2 z + \dots + n_2 = 0, \\ \dots \quad \dots \quad \dots \qquad \dots \end{array} \tag{1}$$

$$\begin{array}{l} a_1 x + b_1 y + c_1 z + \dots + p_1 w + \dots + n_1 = 0, \\ a_1 x + b_1 y + c_1 z + \dots + p_1 w + \dots + n_1 = 0, \\ \dots \quad \dots \quad \dots \qquad \dots \qquad \dots \end{array} \tag{2}$$

The equations being identical in the two series except for the addition of one or more new unknowns $w, \dots$ in (2). Let each of these series of equations be solved by the method of least squares, and let $[vv]_1$ be the sum of the squares of the residuals resulting from the solution of equations (1); $[vv]_2$ be the sum of the squares of the residuals resulting from the solution of equations (2); then, no matter what may be the law of the coefficients $p_1, p_2, \dots$; and even if these coefficients are assigned at random, $[vv]_1$ is always larger than $[vv]_2$."

The conclusion drawn by the writer from this theorem is as follows:

"The method of least squares is used ordinarily to adjust series of observation equations so as to obtain the most probable values of the unknowns. But there is a subtler, and perhaps more important use of the method; when it is employed to decide which of two hypothetical theories has the greater probability of really being a law of nature; or to decide between two methods of reducing observations. In such cases, astronomers not infrequently give preference to the solution which brings out the smallest value of $[vv]$, the sum of the squared residuals. But in the light of the above theorem, it becomes clear that the mere diminution of $[vv]$ alone is insufficient to decide between two solutions, when one involves more unknowns than the other. To give preference to the second solution, it is necessary that the diminution of $[vv]$ be quite large, and that the additional unknowns possess a decided *a priori* probability of having a real existence."

In his paper in the *Astronomical Journal,* No. 521, Mr. Midzuhara says: "This conclusion, perhaps, depends upon the author's misapprehension of the principle of probability. For I believe that to compare the probabilities of the two solutions we must necessarily take

$$\frac{[vv]_1}{m-\mu_1} \text{ and } \frac{[vv]_2}{m-\mu_2},$$

where m expresses the number of observations, and μ_1 and μ_2 are the numbers of the unknown quantities in the first and second solutions, respectively."

In other words, Mr. Midzuhara takes as a criterion for deciding between the two solutions the quantity ordinarily called "mean error of one equation," instead of the sum of the squared residuals. When the number of unknowns in the two solutions is different, these two criteria may give opposite results; the one indicating the first solution as the most probable, the other, the second solution.

It is evident that the practice of astronomers varies in this matter. Mr. Midzuhara, for instance, and doubtless other astronomers, too, use

$$\frac{[vv]}{m-\mu}$$

as the criterion. On the other hand, Bessel was in the habit of using $[vv]$. A good example is to be found in his classic paper on the parallax of 61 Cygni, printed in *Astronomische Nachrichten,* No. 366. He there reduces his observations with parallax terms, and again without them. He decides in favor of the reality of his parallax terms solely on account of the diminution of $[vv]$; and not until after this is decided does he compute the mean error

$$\sqrt{[vv]/(m-\mu)}.$$

This quantity he calculates for the parallax solution only, not for both solutions. So far is he from using it as a criterion.

It would, indeed, appear that very simple reasoning indicates $[vv]$ as the right criterion. If we consider observation equations of the general form:

$$\phi\,(x, y, z, \ldots, n) = o,$$

the ordinary solution determines $x, y, z, \ldots,$ so as to make $[vv]$ a minimum. If there exists a doubt as to whether the form of the function ϕ should be either ϕ_1 or ϕ_2, this fact simply transfers ϕ to the list of unknowns, and we must so determine $\phi, x, y, z, \ldots,$ as to make $[vv]$ a minimum. We shall do this if we make two ordinary least square solutions for ϕ_1 and ϕ_2, the only possible values of ϕ, and prefer that solution which gives the smaller $[vv]$. Since the other criterion may give an opposite result, that other criterion must be wrong.

It may be of interest to add to the above a remark concerning the attractive result obtained by Mr. Midzuhara in his equation (13). This result is

$$[vv]_1 - [vv]_2 = w^2 P_w, \qquad (13)$$

where w is the value of the new unknown, obtained in the solution of our equations (2) and P_w its weight from the same solution. Mr. Midzuhara gives a somewhat extended demonstration of this equation (13); it may, however, be obtained almost directly from a principle demonstrated by Gauss in *Elementis Ellipticis Palladis.** It is there shown that if μ be the number of unknowns, and if the normal equations are solved by the Gaussian method of elimination:

$$[vv] = [nn.\mu],$$

where $[nn.\mu]$ denotes the usual Gaussian auxiliary. In the present case, if there are μ unknowns in equations (1), and $\mu + 1$ in equations (2), we shall have, at the end of our Gaussian elimination:

$$\begin{gathered}[pp.\mu]w + [pn.\mu] = 0,\\ [nn.\mu].\\ [nn(\mu + 1)].\end{gathered}$$

But, according to Gauss's principle:

$$\begin{aligned}[nn.\mu] &= [vv]_1,\\ [nn(\mu + 1)] &= [vv]_2,\end{aligned}$$

and as usual:

$$[nn.(\mu + 1)] - [nn.u] - \frac{[pn.\mu]^2}{[pp.\mu]} \cdot$$

Therefore:

$$[vv]_1 - [vv]_2 = \frac{[pn.\mu]}{[pp.\mu]},$$

But:

$$w = -\frac{[pn.\mu]}{[pp.\mu]},$$

and

$$[pp.\mu] = P_w = \text{weight of } W$$

so that

$$[vv]_1 - [vv]_2 = w^2 P_w$$

This is Mr. Midzuhara's equation (13).

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TABLES FOR THE REDUCTION OF ASTRONOMICAL PHOTOGRAPHS.

BY HAROLD JACOBY.

In 1895 the writer published a paper entitled "On the Reduction of Stellar Photographs, with Special Reference to the Astro-Photographic Catalogue Plates." As indicated in the title, the method there described was intended primarily for the reduction of large series of plates made at the same declination. But ordinary stellar photographs intended for star cluster catalogues, solar or stellar parallax, etc., usually involve so few plates of a single declination that it is not economical to prepare the kind of special tables suitable for a photographic catalogue of the whole heavens. Moreover, *Contribution* 10 of the Columbia Observatory has long been out of print, so that it is now impossible to supply copies to those asking for them.

For these reasons the writer has prepared the present modifications of his method, and has added tables suitable for the reduction of isolated groups of plates made at any declination distant more than fifteen degrees from the pole. The tables will appear in a short time as one of the Columbia *Contributions*.

CALIBRATION OF A PHOTOGRAPHIC PHOTOMETER WEDGE.

BY ORMOND STONE.

RECENT RESEARCHES OF THE HENRY DRAPER MEMORIAL.

BY EDWARD C. PICKERING.

A photograph was shown of the spectrum of λ Cephei, which has a spectrum closely resembling that of ζ Puppis and contains the second series of lines probably due to hydrogen. A method of observing occultations photographically was explained and a printed enlargement of a photograph of the emersion of η Virginis, on December 28, 1904, was shown, which had been taken by Mr. Edward S. King. A rotary motion was given to the plate holder so that the star gave a continuous trail, the time being indicated by a motion given to the plate at regular intervals. It appeared that the star increased in light during emersion for about a third of a second. The principal portion of the paper was devoted to the study of the distribution of the stars according to their spectra. The results were based upon an examination of the Draper plates by Mrs. Fleming. About six thousand plates have been inspected, each showing on the average the spectra of a thousand stars, with small dispersion, and on these all that were peculiar were noted. Using a larger dispersion, about thirty thousand stars have been classified and catalogued. Visual counts of the number of stars in different parts of the sky have little value owing to the uncertainty of the magnitudes. The same might be said of a classification of photometric magnitudes of the stars taken as a whole. It was shown that stars of each class of spectrum should be considered by themselves, as the distribution differs widely. Thus, the Milky Way appears to consist wholly of stars of the first type. The helium or Orion stars have a different distribution, forming a Milky Way of their own, mainly in Orion and Argus. It was shown that the classification of the variable stars, proposed by the writer in 1880, was confirmed by their spectra, and that the latter formed a means of determining the class, in some cases, even better than the light curve.

NOTE ON TWO VARIABLE STAR CATALOGUES.

BY J. G. HAGEN.

Father Hagen presented to the meeting some specimen pages of two Catalogues of Variable Stars, now in preparation, one by the Astronomische Gesellschaft and the other by Professor E. C. Pickering. Of the former catalogue seven pages had been printed for presentation at the astronomical congress in Lund, last September. A copy has been sent to Father Hagen in time for the Philadelphia meeting, but Dr. Mueller's report at Lund came, unfortunately, too late. For this reason only those features of the catalogue could be mentioned that presented themselves to the reader of these seven pages.

More definite explanations could be given on the other catalogue, since Professor Pickering was himself present, and had shown one specimen page previously to several friends. His catalogue will be a "Bibliography of the Variable Stars," with the list of the known maxima and minima, and the sources from which they were taken. Father Hagen brought out the fact that the two catalogues will supplement one another. The catalogue of the Astronomische Gesellschaft will give exact positions and elements of light variations, with very condensed references to all accessible publications, on each variable star. Professor Pickering's "Bibliography" will give fuller details of the spectra of the variable stars from the rich material at the Harvard College Observatory, and will put the lists of known maxima and minima in the convenient shape of tables. While the former catalogue will make a volume of about five hundred pages (quarto size), the latter will have only one-third of this bulk. Both catalogues will be very valuable accessions to our literature on this subject.

USEFUL WORK FOR A SMALL EQUATORIAL. A PROPOSED DISCUSSION.

The discussion was opened by Professor Edward C. Pickering. He stated that measurements of wide double stars might be useful, but that the positions of stars much more than 5″ apart could be better determined by photography, while closer stars required a large telescope. The brightness of stars can now be readily and inexpensively determined with a wedge photometer, and the relative light of the components of close doubles by a polarizing photometer. The Herschel-Argelander method could be usefully applied to faint stars, especially to the components of coarse clusters, and to Durchmusterung zones, inserting all stars brighter than a fixed magnitude. Variable stars of long period can be usefully followed by inexperienced observers, since the range is large. Observations of suspected variables, of Algol, and other short period variables, are likely to be of little value, except when made by observers having long experience. But little useful work could be done with spectroscopes attached to small telescopes. A search for new stars in the Milky Way, and an examination of known nebulæ to see if they are gaseous, as was, perhaps, first done Sir John Herschel, might prove of value. Observations of Jupiter's satellites, comets, sun spots and solar prominences were also mentioned as useful fields of work for instruments of this class.

SEVENTH MEETING

The seventh annual meeting was held December 28 to 30, 1905, at Columbia University, New York. Some sixty members were in attendance and forty papers were on the program.

As usual, a number of pleasant social gatherings occurred during the meeting. On December 29 all lunched together in the department of astronomy, and in the evening were received by Mrs. Henry Draper at her home on Madison Avenue; many members also attended a dinner of the Mathematical Society and the Physical Society on the same evening.

The election resulted as follows:

President	E. C. Pickering
First Vice-President	George E. Hale
Second Vice-President	W. W. Campbell
Secretary	George C. Comstock
Treasurer	C. L. Doolittle
Councilors for 1906-8	E. B. Frost and Harold Jacoby

The council designated Harold Jacoby to act as editor for this meeting.

ABSTRACTS OF PAPERS

SATURN AS SEEN WITH THE EIGHTEEN-INCH CLARK REFRACTOR OF AMHERST COLLEGE OBSERVATORY.

BY DAVID TODD.

This new telescope, which has especially fine definition and a very dark field, was used the past autumn on the Saturnian system. Pending completion of the micrometer, to be employed on the satellites, attention was given particularly to the rings and ball. Differences of illumination in the detail of different zones of the rings were carefully observed and embodied in a drawing. The shadings of the belts on the ball were also set down in estimated positions, and a watch was kept for spots by which to determine anew the rotation time.

TOTALITY-PREDICTIONS FOR THE SOLAR ECLIPSE OF 1907, JANUARY 13-14, IN TURKESTAN AND MONGOLIA.

BY DAVID TODD AND ROBERT H. BAKER.

Attention is called to the importance of this eclipse in advancing our knowledge of the corona. Of eclipses in the immediate future, although a total one occurs every year from 1907 to 1912, that of 1907 is likely to be the most important because the paths of its successors are for the most part inaccessible. The best region for the 1907 eclipse is available by means of railways recently constructed in Russian territory. Also, about six hundred miles northwest of Peking, the eclipse track is rather difficult of access in Mongolia. The writer has computed, among other things, the positions of ten possible stations, exact local times of the four phases, durations of totality, position angle of first contact, and sun's altitude and azimuth at middle of eclipse.

SOME VARIABLE STAR PROBLEMS.

BY S. I. BAILEY.

About ten years ago more than five hundred variables were found in globular clusters; and further discoveries of this kind are possible with instruments of large size among the faintest stars in the clusters already examined, and in clusters which have not yet been searched.

The variables in the clusters ω Centauri, Messier 3 and Messier 5 have now been studied. There are in these clusters three hundred and forty-eight variables; for two hundred and seventy-three of these periods have been determined, averaging about half a day. Changes in brightness are very rapid, and in many cases the regularity of the periods is so great that these stars would serve as good celestial time-keepers.

We have observed the clusters from five to twelve years, obtaining from five to ten thousand returns of maxima, so that periods are obtained which are correct within a few tenths of a second. For seventy-five of the variables periods have not been determined. Of these, sixty-five are too difficult, on account of nearness of other stars, smallness of the range of variation, or both. The remaining ten variables present peculiarities not yet understood.

While our observations for most of these variables are satisfied by a simple, uniform period, there are a number of cases in which it has been necessary to introduce a second term, implying a secular variation in the period. Several have been found which are best explained by the supposition that they are doubles, both components varying with the same period but with alternate maxima.

The presence of large numbers of variables in some clusters, and few, or none, in others, calls for an explanation. It may be that the axes of revolution of all members of such stellar systems are parallel. Variability, if associated with revolution, might then depend on the direction from which the system is seen. Stars which vary for us may be unvarying when seen from some other point in space. Again, variability doubtless marks an epoch in the development of stars. This epoch may be in the past for some, present for others, and future for still others.

The typical form of light-curve for variables in clusters is difficult to explain on the theory of axial revolution. But Dr. R. H. Curtiss has shown recently that a relation exists between motion in the line of sight and variations in brightness in the case of W Sagittarii. Much may be learned by an extension of this research to other variable stars.

MAXIMA AND MINIMA OF VARIABLE STARS OF LONG PERIOD.

BY ANNIE J. CANNON.

The original form of the bibliography of variable stars undertaken several years ago at Harvard College Observatory, for which all the material has been collected, was recently modified owing to duplication of much of the work by the Gesellschaft Committee in their proposed complete "Catalogue of Variable Stars." Tables of observed maxima and minima for class II, or long period stars, are now being printed. Proof sheets of such tables for stars between zero and six hours right ascension are now submitted to the Society. These tables give in successive columns, calendar date of the observed phase, Julian date, magnitude, name of observer, reference, epoch and residual from a period computed by a formula following the name of the star. Residuals have been calculated without the use of a second term in the formula: by plotting residual curves the form of correction to the period may often be found. Residual curves of T Andromedæ, *o* Ceti and S Ursæ Majoris were shown to the Society. The residual curve of S Ursæ Majoris, drawn from observations extending from 1843 to 1905, shows the need of a sine term in the formula. The residual curve of T Andromedæ is interesting in connection with the discussion concerning the period of this star soon after its discovery. Observations of o Ceti have extended over a longer time than those of any other long period variable. The residual curve, computed from observations since 1596, shows many irregularities and explains the difficulty of deducing a formula to represent the phases of this star.

It is hoped that these tables, by bringing together so much material in a convenient form, may prove of some use in investigating the variables of long period.

SYSTEMATIC STUDY OF FAINT STARS.

BY E. C. PICKERING.

This paper described work that has been in progress at Harvard College Observatory, during the past five years, in studying the faint stars. The sky was divided into forty-eight exactly equal parts, as explained in detail in *Harvard Annals,* XIV, 477, and used in various publications of the Observatory during the last twenty years. Portions of the sky, one degree square, in the centers of these regions, have been chosen for detailed study. The epoch employed is 1900. A sequence of fifteen stars of magnitudes 7.5 to 12.5 has been selected and measured with the twelve-inch meridian photometer, in each of these regions. Photographs have been taken with two hours' exposure, using the twenty-four-inch Bruce telescope, showing stars of magnitude 16, and brighter, and these have been enlarged to a scale of $20'' = 1$ mm. Photographs of the spectra with small dispersion, showing stars to magnitude 11, have been taken, and charts in and out of focus have been obtained. Photographs of these regions have also been made at the altitude of the pole, and for comparison the pole itself was photographed with the same exposure upon the same plate. The photographic magnitudes of all stars in the sequences mentioned above can thus be determined on the same scale. The measurement of photometric magnitudes from isochromatic plates is now in progress.

Nearly all photographs of the thirty-six regions north of declination — 30°, and many of the others, have been completed; the entire work would probably have been finished, had the appropriation of 1902 been continued.

DISTRIBUTION OF THE STARS.

BY GEO. C. COMSTOCK.

This paper deals with the extent of the visible universe and with the arrangement of the stars composing it. The data available and utilized for the discussion are of two kinds, (*a*) the number of stars per square degree of the sky as shown by the enumerations and gauges of Pickering, Argelander, Seeliger, Celoria and the Herschels, extending from the brightest stars down to the faintest visible in the Herschel telescope, about the fourteenth magnitude; and (*b*) the average distances of the stars of each individual magnitude. These distances are obtained from a combination of the velocity with which the solar system moves through space and the resulting apparent displacement of the stars in the sky, the solar motion being determined spectroscopically and the displacement of the stars by means of the meridian circle. Kapteyn has obtained in this way the mean distances of stars from the third to the ninth magnitude; the present paper supplements this by a new determination of distances for stars between the ninth and eleventh magnitudes.

Based upon a part only of the above material, current astronomical doctrine affirms that the visible universe is a stellar system of limited extent whose boundaries, at least in some directions, lie within reach of our present telescopes. This view is opposed in the present paper, where it is pointed out that the evidence in favor of limited extent is obtained by ignoring two important factors of the problem; when these factors are taken into account the supposed evidence vanishes.

The first, and more important, of these factors relates to the intrinsic brightness of the stars. It has been commonly assumed that the fainter stars appear faint because of their greater distance from the earth and that there is no reason to suppose them to be intrinsically less luminous than the bright ones. The first part of this statement is unquestionably correct as far as it goes; the second part is wholly wrong. The faint stars, according to the writer, are less luminous than the bright ones, and stars of any given magnitude emit, on the average, only ninety per cent. as much light as do stars a magnitude brighter.

The second factor omitted in previous discussions is not here ignored, but rejected as useless. The known existence of dark matter or cosmic dust scattered through space leads naturally to the supposition that it may in some manner effect the transparency of interstellar spaces and cause an appreciable diminution in the light of fainter stars. Although this view has been rejected from current theories, it is evident from mathematical discussion of the data here considered that there is such an absorption and that approximately five per cent. of light is lost in transmission over a distance equal to a million times the diameter of the earth's orbit.

In abandoning the concept of a stellar system of limited and measurable extent the writer considers, provisionally, the consequences that result from the hypothesis of a system indefinitely extended on every side, with substantial uniformity in the direction of the Milky Way but thinning out on either side of the Milky Way, because the stars are here less numerous, or less brilliant, or because a denser cosmic dust more effectually quenches their light. It is impossible, now, to decide between these alternatives, but something of the kind is operative, and any one of the alternatives or a combination of all suffices to explain every feature of the stellar system for which the current theory accounts. The new hypothesis also brings out features hitherto unrecognized or unexplained.

The stars are not all of one kind, but differ among themselves in physical condition and properties which the spectroscope is able to detect and analyze. By far the larger part of the stars fall into one of two classes which the spectroscopists designate as type I and type II, and which they regard as different stages of development of the individual, a star of type I passing over with increasing age into type II. Now Professor Pickering has shown recently that these stellar types are not scattered indiscriminately throughout the sky, but that the younger stars, type I, show a more pronounced tendency to cluster along the Milky Way than do the mature ones, and this tendency grows more and more pronounced with diminishing brightness of the stars. It is difficult to see why this should be so; why one part of the universe should lag behind the rest in development, but the new hypothesis indicates at once that such is not the case. The distribution found by Professor Pickering is only an apparent one depending upon the known fact that the type I stars are intrinsically brighter than their companions of type II. This fact alone in a system such as is here supposed would produce an increasing accumulation of faint, and therefore distant, stars of this type in the region adjoining the Milky Way, although, in fact, the two types may be everywhere distributed with a uniform ratio of frequency.

Other matters can be touched upon here in a summary way only. It is an immediate consequence of the present hpothesis that any considerable group of stars in a part of the sky remote from the Milky Way must on the average be nearer to us than a group of similar stars in the Milky Way. Although this relation has not been recognized hitherto, the writer finds from his own observations of faint stars between the ninth and twelfth magnitudes that such is the fact, the stars in the Milky Way being twenty-eight per cent. more distant than the mean of all other stars. It is commonly stated that the brightest stars emit an amount of light enormously greater than that given by the sun, 1,000 or 10,000 times as much, but from the measured magnitudes and distances of the stars it appears that while the large majority are brighter than the sun, few if any are more than two hundred times as bright.

Much of the investigation contained in this paper is summed up in a series of formulas, one of which shows the number of stars in the sky that are brighter than a given magnitude, *e. g.*, the tenth. Another shows the average distance of the stars of any assigned magnitude. A partial proof of the substantial accuracy of the numerical work contained in the paper is found in the fact that this last formula, although based solely upon distances of the fainter stars, derived by an indirect process, is in excellent agreement with the directly measured distances of the brightest stars.

PHOTOMETRIC INVESTIGATIONS.

BY F. H. SEARES.

This paper is a summary of results in an investigation of the wedges belonging to a Pickering equalizing stellar photometer. Two wedges were examined; one of photographic film, the other of shade glass. Absorption curves were determined by means of a disc photometer. The magnitude scales underlying these curves were then compared with that of the Müller and Kempf catalogue of Pleiades stars. Magnitude differences of twenty-one pairs of stars were measured and the results compared with the catalogue. The stars observed range from 7.24 to 10.76 magnitudes; the magnitude differences, from 0.80 to 3.52 magnitudes, with an average of 1.8 magnitude.

Eight observations were made with the shade glass wedge upon each pair. With three exceptions, each pair was measured upon at least four different nights. The results for this wedge are: probable error of a single observation of four comparisons, ± 0.066 magnitude; average deviation of mean magnitude difference from the catalogue difference, 0.07 magnitude; deviation of wedge magnitude scale from the scale of Müller and Kempf, for the range 8.2—10.0 magnitudes, + 0.028 magnitude. The scale agreement is to be considered satisfactory, since the deviation is not greater than may arise from personality alone.

. Results for the photographic wedge were derived from five observations upon each pair, measured on three nights. The results are: probable error of a single observation of four comparisons, ± 0.078 magnitude; average deviation from the Müller and Kempf magnitude difference, 0.12 magnitude; scale difference, — 0.073 magnitude. The two scales can be brought into agreement by multiplying the ordinates of the absorption curve of the photographic wedge by the factor 0.961.

The photographic wedge has been discarded in favor of that of shade glass.

Details of the investigation are to be found in *Laws Observatory Bulletin*, No. 7.

SOME PECULIAR SPECTRA.

BY MRS. W. P. FLEMING.

The examination of stellar spectrum photographs at Harvard College Observatory, forming part of the work of the Henry Draper Memorial, has enabled us to follow new stars until they became gaseous nebulæ, too faint for observation. Since we can pass from gaseous nebulæ to stars of class O, or type V, in which characteristic bright lines extend from wave-length 4600 to 4800, thence to stars having several hydrogen lines bright with dark lines of helium also present, and from the latter through classes B, A, F, G, K and M, we may assume that we have a key to the formation of the stellar universe.

In putting together results from an examination of variable stars whose spectra are of class Md it was found that a few stars were assigned to several subdivisions extending from Md 1 to Md 10, the most marked case being S Carinae. Further examination showed actual changes in the spectrum, which probably (as in the case of β Lyræ) follow closely the variations in light. R Scuti also shows changes, and quite recently R Cygni, another long period variable, has been added to this list.

The spectrum of the star (now known to be a gaseous nebula) — 12° 1172, magnitude 9.2, when found on Harvard photographs, has always led to an examination of the list of novæ before that of nebulæ, since in this spectrum the bright nebular lines at wave-lengths 5003 and 5007 are quite faint, the hydrogen lines, $H\zeta$, $H\epsilon$, $H\delta$, $H\gamma$, and $H\beta$ are bright and of normal intensity, while the most marked feature is the broad bright line at wave-length 3724. This is not generally well defined in photographic spectra of gaseous nebulæ, in which the strong line in the violet end is 3868, of slightly shorter wave-length than $H\zeta$.

The star Z.C. 18^h 1935, magnitude 9, shows a peculiar form of spectrum not yet assigned to its class. The continuous spectrum contains strong, dark bands of which the most marked extend from 4650 to 4710. This agrees closely with the strong characteristic bright line in spectra of the fifth type. A few other stars with similar spectra have been announced in Harvard Circulars. The variable star—Crucis, R.A. $= 12^h\ 50^m.7$, Dec. $= -57° 21'$ (1900), has a spectrum similar to that of Z.C. 18^h 1935, but in it the hydrogen lines $H\gamma$ and $H\beta$ are bright, as in variables of the earlier subdivisions of class Md.

No other spectrum has yet been found on these photographs like that of π^1 Gruis, but that of R Cygni, as photographed on December 2, 1890, bears a closer resemblance to it than any other spectrum yet photographed here.

BURNHAM'S FORTHCOMING GENERAL CATALOGUE OF DOUBLE STARS.

BY EDWIN B. FROST.

With Professor Burnham's permission a brief statement is made here regarding this important undertaking, the basis for which has existed in manuscript for many years. A grant from the Carnegie Institution in 1903 made publication possible, and rather more than four-fifths of the work has now been set up and electrotyped. It includes about thirteen thousand double stars north of 31° south declination.

Part I consists of a tabular catalogue, in quarto form, giving in order of right ascension the position, first measures, observer and other data, in eleven columns.

Part II contains notes on the stars, selected measures (up to date of printing), showing motion or otherwise, present relation of the components, and references to all published measures.

This part will include some 10,000 unpublished observations made at the Yerkes Observatory in the last five years, and about as many more furnished principally by Messrs. Aitken and Hussey of the Lick Observatory and Eric Doolittle of the Flower Observatory.

It is hoped that the work may be published during the year 1906.

PHOTOGRAPHIC PHOTOMETRY OF RAPIDLY CHANGING VARIABLE STARS.

BY J. A. PARKHURST AND F. C. JORDAN.

The light-curves of certain rapidly changing variables were determined from a series of short exposures on a single plate, taken with the twenty-four-inch Yerkes reflecting telescope. In order to utilize fully the advantages of the method, (1) the exposures were made short, so as not to smooth out the light-curve; (2) a number of comparison stars were used; (3) diameters of the focal images were measured to 0.001 mm. under the microscope.

The variable stars investigated by this method were:

Star.	Number of Plates.	Number of Exposures.
U Cephei,	1	20
W Ursæ Majoris,	3	35
RW Tauri,	7	55
14. 1904 Cygni,	8	53
32 Cassiopeiæ	4	72

Results.—(1) U Cephei. The well-known curve was reproduced, with average residuals of ± 0.04 magnitude. (2) W Ursæ Majoris. The curve is similar to that drawn by Müller and Kempf; with corrections to their ephemeris for epoch 1777, + 2^m; epoch 1945, + 13^m. (3) RW Tauri. The range is 3¼ magnitudes, the most rapid change at the rate of three magnitudes per hour; the correction to Pickering's ephemeris for epoch 2598 is + 38^m; epoch 2602, + 37^m. (4) 14.1904 Cygni. The range is 0.7 magnitude, the period is $3^h\ 1^m\ 26^s.4$; the curve resembles the "cluster type." (5) 32 Cassiopeiæ (suspected variable). No variation was found beyond accidental errors of measurement, the mean residuals for the four plates, each covering the greater part of the suspected period, being ± 0.05, ± 0.05, ± 0.06 and ± 0.04 magnitudes.

SPECTROGRAMS TAKEN AT DAROCA, SPAIN, AUGUST 30, 1905 U. S. NAVAL OBSERVATORY ECLIPSE EXPEDITION.

BY S. A. MITCHELL.

Five spectrographs were employed; three gratings and the other two alike having a dispersion of one weak prism. Weather conditions were perfect. Results with the two larger instruments are as follows:

1. *Parabolic grating*, diameter four inches, with 14,438 lines to the inch and a focal length of five feet. The dispersion of this instrument is about the same as the Bruce three-prism spectrograph of the Yerkes Observatory and the Mills spectrograph of the Lick Observatory. The distance from D_3 to H is almost exactly seven inches, the total length of the photographed spectrum being 9.5 inches. The definition is excellent throughout the whole length of the flash, which extends from D_3 to λ 3300, and shows a very great number of lines.

The spectrum taken near mid-totality shows some interesting coronal rings. The green coronium ring appears very plainly and two rings in the extreme ultra-violet are just as prominent on the photograph as the green ring. As the plate used has a photographic action which is just as intense in the ultra violet as in the green, it would seem that the corona is very rich in ultra-violet rays. The following coronal lines are seen at approximately, λλ 3381, 3388, 3455, 3643, 3984, 4228, 4565, 4618 and the coronium line at λ 5303.

2. *Flat Grating*, with 15000 lines to the inch, and a ruled surface 3½ x 6 inches. The lens is a Clark five-inch visual with a focal length of about six feet. On the photographs the distance from D_3 to H is eight inches. In the flash spectrum lines can be seen beyond D toward the red almost to C. This is the end of the spectrum most desired, and the focus is excellent from F to the extreme of the red. The green coronium ring also appears on the plates taken near mid-totality.

OBSERVATIONS OF RADIAL VELOCITIES.

BY EDWIN B. FROST.

The four principal programs of observations with the Bruce spectrograph of the Yerkes Observatory are: (1) standard velocity stars; (2) stars of Orion type; (3) visual binaries; (4) miscellaneous variable stars. About 500 plates of over 100 stars of program (2) have been measured (many in duplicate); three or more satisfactory plates have been obtained of 135 stars of the Orion type, and one or two plates of forty more.

It is important to secure at this epoch good determinations of the sight-line velocity component for visual binaries of program (3). With Burnham's assistance an observing list was compiled containing 120 stars known to be binary, and bright enough to be observable with the Bruce spectrograph, at least with one prism. Preference was given to pairs differing in magnitude sufficiently to prevent confusion of spectra, and for which the brighter component would have fairly sharp lines.

The writer's measurements of P Cygni show that the strong and broad *bright* components of the hydrogen and helium lines have only a very small displacement, corresponding to a radial velocity of about 12 km. per second of approach; while the *dark* components, sharply defined at each margin, and comparatively narrow, yield very large displacements toward the violet, differing for hydrogen and helium. If interpreted by Doppler's principle, the velocities (approach) would be about 190 km. for hydrogen and 150 km. for helium; the three blue silicon lines seem to have no bright components, and from these a consistent value of about 80 km. (approach) is derived. An attempt to account for these differences as a result of overlapping of the dark and bright lines has not yet been successful. A comparison with Belopolsky's observations of this star made in 1899 indicates that the displacements are not variable. Physical cause may be responsible for this remarkable spectrum.

Spectrograms of the variable star RT Cygni, obtained in conjunction with Parkhurst, when the star was of magnitude 7.5, showed bright $H\gamma$ and $H\delta$ with an exposure as short as 45 minutes. These bright lines were very strongly displaced toward the violet, corresponding to an approaching radial velocity of 100 km. per second. It now seems probable that this did not vary during the first half of December, 1905, which period included the five plates obtained.

It is possible that variations occur in the bright lines of Pleione, which were very weak, if present, on three plates recently obtained, although they were shown on spectrograms taken by the writer at Potsdam in 1891, and on Harvard plates. The spectrum of α Columbæ is peculiar, and μ Orionis has been found to be a spectroscopic binary.

THE SOLAR CORONA, AS OBSERVED BY THE U. S. NAVAL OBSERVATORY ECLIPSE EXPEDITION, AUGUST 30, 1905, AT PORTA CŒLI, SPAIN.

BY G. H. PETERS.

The observing station was near the eastern coast of Spain, north of Valencia. It was located about ten miles north of the southern limit of the shadow path, for the purpose of studying especially the regions about the southern pole of the sun.

The corona at this eclipse, occurring near the sun-spot maximum, had a structure entirely different from those of 1900 and 1901. The polar rays were nearly obliterated by numerous streamers and wings, which were nearly equally prominent throughout the whole circumference. The entire corona exhibited a mass of fine details, considerably striated, and to a great extent intermingled.

VACANT REGIONS OF THE SKY.

BY E. E. BARNARD.

There are two distinct classes of these vacancies. The commonest form has all the appearance of real openings in the bed-work of stars —through which there is an uninterrupted view of space. The other class, mainly found in Ophiuchus and Scorpio, suggest the presence of a nebulous substratum among the stars. The appearance of these latter regions is widely different from ordinary vacancies, their marked features being areas devoid of stars, yet apparently filled with some other substance in which blacker holes occur, as if there were a nebulous veiling pierced with holes and rifts.

The most remarkable of these regions are those about θ and ρ Ophiuchi, the latter being connected with the great nebula of ρ Ophiuchi. From this latter region a straggling vacant lane runs easterly for a distance of some 15° and connects with a great chasm just east of θ Ophiuchi. Some vacancies near this latter star are very small and very curious, all showing more or less the appearance of vacancies within vacancies.

Attention is called to the probable relative smallness of stars forming the bedwork of the Milky Way near Antares. The small stars here seem to be intimately related to the great nebula of ρ Ophiuchi. But the nebula certainly involves such naked eye stars as ρ Ophiuchi and σ Scorpii, and appears to involve even Antares. Reasoning from this that the nebula, the small stars of the Milky Way, and the brighter stars here, are at relatively the same distance from us, the natural conclusion is that the apparently great difference in size between the above-named stars and the groundwork of small stars of the Milky Way at this point is not so much due to a greater distance of the smaller stars as to their being actually very much smaller.

DETERMINATION OF ABSOLUTE STAR POSITIONS BY PHOTOGRAPHY.

BY E. C. PICKERING.

It is proposed to determine the absolute positions of a zone of equatorial stars by means of photography. A telescope of long focus is pointed to the intersection of the equator and meridian, and motion is given to the photographic plate equal to that of the stars. Reference points are furnished by holes through which a small incandescent light shines on the plates. Current is sent from a standard clock, which should be kept underground at a uniform temperature and pressure. As observations would extend over one year at least, errors depending on the sun's position should be eliminated. The only parts of the apparatus that need be rigid are the objective and the plate carrying the reference holes. So long as the images, which have an exposure of about a minute, are sensibly circular, or uniformly elongated, slight motions of the photographic plate are unimportant. The principal advantage of this method is that stars as faint as the tenth or eleventh magnitude may be recorded, and a large part of the entire region may be photographed in a single night. It might be better to photograph a zone a little north of the equator in mid-winter, at a station so far north that observations could be made continuously during twenty-four hours. Many forms of small systematic error would thus be eliminated.

THE POLARIS VERTICAL CIRCLE METHOD OF DETERMINING TIME AND AZIMUTH.

BY F. H. SEARES.

The vertical circle method of observing for time and azimuth has been known for a century or more, is capable of affording very precise results, but has never found general acceptance on account of a lack of satisfactory methods of reduction. The most important methods have been devised by Döllen and Harzer. The formulæ of Döllen are not sufficiently accurate for many purposes; moreover, the ephemerides necessary for the use of his formulæ are no longer published. The method of reduction proposed by Harzer lacks nothing in precision, but the calculations are unnecessarily long. *Laws Observatory Bulletin,* No. 5, contains a method which affords the desired precision, and permits of a saving of three-tenths in the labor of calculation as compared with the process of Harzer. The present paper separates the features which are essential for the practical application of the method from certain purely theoretical considerations contained in *Bulletin* No. 5, and is intended to exhibit more clearly the simplicity and brevity of the operations involved in the employment of the writer's formulæ.

Although it is not contended that the vertical circle method can profitably replace the older methods in all cases, the following advantages are claimed:

1. A saving in labor when it is necessary to determine both time and azimuth.
2. A gain in precision and a saving in labor in the determination of time with unstable instruments, especially when it is desirable to secure all possible accuracy.
3. A frequent saving in time and labor, irrespective of whether the instrument be stable or unstable, when it is necessary to work through clouds.
4. When applied to the engineer's transit, it affords a very simple and precise method of determining time in the field, and frees the observer from any necessity of waiting for an elongation of Polaris in order to secure observations for azimuth.

DETERMINATION OF ADJUSTMENT ERRORS FOR THE POLAR AXIS OF AN EQUATORIAL.

BY ERIC DOOLITTLE.

The method consists in measuring the position angle of a pair of stars close to the pole. Each measure gives an equation for determining the position angle, supposed unknown, and the instrumental errors. From several measures at different hour angles the latter can be determined with a degree of accuracy probably higher than by any method in which the circles of the instrument are used. The ordinary formulæ must, however, be considerably modified for this purpose.

Two determinations of the error of adjustment for the eighteen-inch equatorial belonging to the Flower Observatory were made, the results agreeing within 1 second, and the probable error of each result being less than 1.5 seconds.

The advantages of the method are that observations are very easily made, that there is no moving of the dome or observing chair, and that the time need only be known very roughly. The setting circles are not read, and hence their errors of graduation do not affect the result. The disadvantage is that the subsequent labor of reducing positions of polar stars to apparent place is so great as to preclude the method becoming of much practical value.

THE HOUGH DOUBLE STARS.

BY ERIC DOOLITTLE.

Work on the 622 double stars discovered by Hough has been carried on, only about fifty of them now remaining unmeasured. It is hoped that these may be finished during the present year.

THE OBSERVATIONS OF SUN-SPOTS BY THE LATE C. H. F. PETERS.

BY EDWIN B. FROST.

It has been for many years a matter of regret to students of the sun that the solar observations by this careful observer have remained inaccessible. In 1904 the Carnegie Institution decided to publish them, and the writer was requested to edit them.

The observations cover the decade from May 1860, to May 1870, with some interruptions, and more than 13,000 heliographic positions of spots were accurately determined on over 1,100 days. The first year's observations overlap the last year of Carrington's series, and Spoerer's observations at Anclam extend from 1861 to 1871. While it is thus decidedly unfortunate that Peters's results could not have been published thirty-five years ago, their value for comparative purposes is still great, and they were obtained with better instrumental equipment than the other two contemporary series.

The manuscript was supposed to have been left by Dr. Peters in a condition for printing, but some abridgment of the tabular data has now seemed desirable. No manuscript has been found describing the method of observation or procedure used in obtaining the constants of reduction, which constants in fact have to be inferred. The galley proofs of the tabular part have now been read, and it is hoped that the volume can be issued during 1906.

COMPUTED TRACKS AND TOTALITY-DURATIONS OF TOTAL SOLAR ECLIPSES IN THE TWENTIETH CENTURY.

BY DAVID TODD AND ROBERT H. BAKER.

Their tracks of visibility have been calculated and charted as accurately as possible. This has been done from Oppolzer's tables (*Canon der Finsternisse*), the most reliable at present in existence, and Oppolzer's own charts corrected. The longest eclipses of the next half-century are:

1911, April 28,	duration 5½ minutes.
1919, May 29,	duration 7 minutes.
1922, September 21,	duration 6½ minutes.
1923, September 10,	duration 4 minutes.
1926, January 14,	duration 4½ minutes.
1929, May 9,	duration 5½ minutes.
1937, June 8,	duration 7½ minutes.
1940, October 1,	duration 6 minutes.
1944, January 25,	duration 4½ minutes.
1947, May 20,	duration 5½ minutes.
1955, June 20,	duration 7½ minutes.

AN ANALYTICAL METHOD OF DETERMINING ORBITS OF NEW SATELLITES.

BY A. O. LEUSCHNER.

This paper contains formulæ for the computation of osculating elements of a material point moving under the attraction of more than one mass, from three or more geocentric observations. It is applicable to satellites, comets or asteroids which are greatly disturbed during the time over which the observations available for the computation of an orbit extend. The resulting osculating elements are the elements that would result from a solution irrespective of the perturbations if the observed right ascensions and declinations of the material point could be corrected in advance for the perturbations, starting with an arbitrary epoch of osculation within the range of the observations. As in the short method proposed by the writer for deriving orbits of comets and asteroids, the right ascension (α) and declination (δ), their velocities (α', δ'), and accelerations (α'', δ''), are determined empirically for the date of an observation near the middle of the available data. Being accurately determined from the disturbed geocentric coordinates, these six quantities correspond to the osculating elements.

In the case of a distant satellite of Jupiter disturbed by the sun, let the geocentric coordinates and distance of the satellite be α, δ, ρ, and of Jupiter (α), (δ), (ρ). Let the Jovicentric coordinates and distance of the satellite be x, y, z, r, and the corresponding heliocentric quantities $[x]$, $[y]$, $[z]$, $[r]$. Further, let $(k)^2 = m\,k^2$, where m denotes the mass of Jupiter.

Then from the equation of motion of the satellite referred to Jupiter's center as origin, we have,

$$\frac{d^2x}{dt^2} + (k)^2\frac{x}{r^3} = -k^2\left\{\frac{[x]}{[r]^3} - \frac{(x)}{(r)^3}\right\},$$

and the corresponding equations in y and z, three equations are deduced which give ρ, ρ', ρ'', in terms of known coordinates, velocities and accelerations, and in terms of the unknowns (r) and $[r]$. The complete expression for ρ is

$$\rho = \frac{A}{r^3} + \frac{B}{[r]^3} + C,$$

A, B and C being expresed in terms of known quantities. The solution of this equation together with the equations

$$[r]^2 = R^2 + \rho^2 - 2R\rho \cos [\psi]$$
$$r^2 = (\rho)^2 + \rho^2 - 2(\rho)\rho \cos (\psi)$$

gives all the values of ρ corresponding to the various possible solutions. In practice, the solution of these equations is very simple. From ρ the value of ρ' is derived. The remaining steps leading to the osculating elements are similar to those of the short method. The short method, itself, is a special case of that under discussion, terms depending upon the mass of Jupiter dropping out and the motion being referred to the center of the sun.

Among other special cases of this analytical method is that obtained by omitting the terms depending upon the solar attraction in these formulæ. The resulting formulæ will then be those for the determination of the undisturbed motion of the satellite. The general method is applicable to material points moving under the attraction of any number of masses. The method presents the advantage that it is free from all arbitrary assumptions, whether introduced with the assistance of graphical construction or otherwise, and that it reveals all possible sets of osculating elements which will represent the disturbed geocentric positions given by observation.

PLANETARY INVERSION.

BY WILLIAM H. PICKERING.

This paper was illustrated with a gyroscope. The subject has already been treated theoretically in other places, and the present paper is therefore purely experimental. The gyroscope was arranged so that it could turn about an axis passing through the plane of the wheel, and also about a vertical shaft which supported it.

According to the nebular hypothesis, when the rings or spirals surrounding a central sun broke up into planets, each planet would, by Kepler's third law, have a retrograde rotation. The fact that nearly all planets rotate in the opposite direction has always been held a serious objection to the hypothesis, and several different suggestions have been offered to explain the discrepancy. None of these even attempted, however, to explain the rotation of Uranus, which lies in a plane practically at right angles to the orbit.

The gyroscope was set spinning in a retrograde direction. The stand which supported it was then held by the speaker at arm's length, while he gave himself a slow direct rotation upon his feet, thus imitating the motion of a retrograde planet in its orbit. By applying friction to the vertical shaft, and thus introducing the effect of an annual tide upon a planet, it was shown that the gyroscope would slowly shift its plane of motion. Its equator first became inclined to the orbit, like that of Neptune, and later nearly at right angles to it like that of Uranus. The shifting of the plane of rotation continuing in the same direction, the rotation itself now became direct, and its plane gradually approached that of the orbit. The inclination was before long the same as that of Saturn, and later the same as that of Jupiter. The two planes now practically coincided, and the rotation and revolution were in the same direction.

When this became the case the plane of rotation had reached a position of stable equilibrium, unaffected further by tidal action. Reversing the direction of orbital motion again shifted the plane of rotation, which now also became retrograde, showing that the phenomenon exhibited was a real property of the gyroscope, as had indeed been proved theoretically, and was not an effect due to some faulty construction of this particular instrument.

TABLES FOR THE REDUCTION OF PHOTOGRAPHIC MEASURES.

BY BURT L. NEWKIRK.

These tables are intended to facilitate the transformation from standard rectangular coordinates to differences of right ascension and declination as well as the converse transformation, and the correction for refraction, including terms higher than the first order in the measured coordinates. Being intended primarily for use in the reduction of plates made with certain lenses belonging to the Berkeley Astronomical Department, which cover a field some ten degrees in diameter, they are applicable to stars whose right ascensions differ from that of the center of the plate by five degrees or less and whose declinations differ from that of the center of the plate by five degrees or less, no matter what the declination of the center of the plate may be.

The tables for the transformation of standard rectangular coordinates into intervals of right ascension and declination and its converse are based upon Professor Turner's fundamental relations:

$$\eta = \tan\,(d - \delta_0)$$
$$\tan d = \tan \delta \sec\,(\alpha - \alpha_0)$$
$$\xi \sec d = \frac{\tan\,(\alpha - \alpha_0)}{\cos\,(d - \delta_0)}$$

Three tables have been constructed, giving quantities *A, B, C,* such that, given:

$$\begin{aligned} &\alpha_0,\ \delta_0,\ \xi,\ \eta, \\ &d - \delta_0 = k\eta - A, \\ &\alpha - \alpha_0 = k\xi \sec \delta - C, \\ &d - \delta = \mathrm{B}, \end{aligned}$$

giving:

$$\delta - \delta_0 = d - \delta_0 - (d - \delta),$$

or, given:

$$\begin{aligned} &\alpha_0,\ \delta_0,\ \alpha,\ \delta, \\ &d - \delta = B, \\ k\eta &= d - \delta_0 + A, \\ k\xi \sec d &= (\alpha - \alpha_0) + C. \end{aligned}$$

In which

α_0, δ_0 = coordinates of center of plate;
α, δ = coordinates of star;
ξ, η = standard coordinates of star;
k = scale value factor.

The tables for the determination of the refraction correction are also based upon formulas of Professor Turner:

$$\Delta x = (X - x)t,$$
$$\Delta y = (Y - y)t,$$
$$t = \frac{1 + x^2 + y^2}{\mu 1 + xX + yY}$$

In which

$$\left.\begin{matrix} X, Y \\ x, y \end{matrix}\right\} = \text{true coordinates of zenith and star projected on plate;}$$
$$\left.\begin{matrix} \Delta x \\ \Delta y \end{matrix}\right\} = \text{projections on plate of } \textit{total} \text{ displacement of star due to refraction;}$$
μ = refraction constant.

The tables are so constructed that the terms of Δx and Δy, which represent the displacement common to the star and the center of the plate, have been omitted. Those terms of Δx which are proportional to x and the terms of Δy which are proportional to y have also been omitted, these corrections being automatically applied in the determination of the plate constants.

A CONTRIBUTION ON ASTRONOMICAL REFRACTION.

BY RUSSELL TRACY CRAWFORD.

An investigation of the constant of refraction was made in the year 1899 which resulted in the discovery that this so-called constant is a function of the zenith distance. The observations were made with the Repsold meridian circle of the Lick Observatory and reduced by a method which is the converse of Talcott's method of determining latitude.

This method has both its advantages and disadvantages. Among the former, the most important are: first, total elimination of the latitude, and hence also of its variation; second, elimination of the nadir reading; third, there is no wait of twelve hours or six months in order to observe a star at both culminations; fourth, only one half of any error of observation or in the declinations used enters into the reductions; and, finally, the simplicity of the observations.

The greatest disadvantage lies in the fact that the declinations have to be considered known. But by taking fundamental stars, such as those of Professor Newcomb's new "Fundamental Catalogue," and by taking a large number of these stars, this difficulty will be nearly eliminated.

Two independent series of observations were made for this investigation. One was made during the summer months, giving

$$\Delta \log \mu = 0.000101\ (56^\circ.6 - z).$$

The other made during the winter months gives

$$\Delta \log \mu = 0.000117\ (59^\circ.3 - z).$$

Combining these into one solution, the two constants of the expression become

$$+\ 0.000108 \pm 0.000010 \quad \text{and} \quad 58^\circ \pm 8^\circ,$$

so that the Pulkowa tables should be corrected by

$$\Delta \log \mu = 0.000108\ (58^\circ - z)$$

where z is the zenith distance in degrees.

The efficiency of tables constructed by applying this correction to the Pulkowa tables may be shown by comparing a series of observations reduced by the two. In his preliminary reductions of his observations of the Piazzi southern stars, Professor Tucker has used the Pulkowa refractions. In his final reductions, he has corrected his declinations for errors in refraction which are given as a function of the zenith distance. Auwers has published further corrections to reduce Tucker's results to his fundamental system (*Abhdlg. z. d. Astronomischen Nachrichten,* No. 7). The differences between the corrections Auwers — Tucker and those resulting from this investigation are less than the probable errors of observations found by Tucker.

A SOLAR PLANISPHERE.

BY SARAH F. WHITING.

In connection with the students' laboratory work at Whitin Observatory, Wellesley College, a device for working problems in relation to the hours of day, night and twilight, at different latitudes at different times of year, has lately been worked out chiefly by E. Rebecca Ellis, assistant. We do not find this simple contrivance, which we call a solar planisphere, elsewhere described.

Using a stiff card, the sphere is projected on the plane of the meridian. The horizon and twilight circles eighteen degrees below are also drawn. Upon another smaller circular card, pivoted to the first at its center, the six-o'clock hour-circles through the poles, the equator, and diurnal paths of the sun at the solstices are projected in straight lines. Harmonic projections of the hour-circles for every twenty minutes are marked on these.

By revolving the movable card the pole can be set to the proper elevation for any latitude, and the number of hours of darkness, twilight and daylight can be read. The time of sunrise and sunset and the meridian altitude of the sun at noon or midnight can also be measured.

These fundamental phenomena should be made clear even in preparatory schools, but from our observation of college students it is evident they are not. To put such a piece of apparatus into the hands of each student, with which he can solve a set of problems, would be another move in the direction of individual laboratory work in general astronomy which it seems so difficult to secure.

The model has been entrusted to the Arthur Hall Scientific Company, of Boston, for reproduction, in the hope that it may be of service.

THE REPSOLD MEASURING APPARATUS OF THE STUDENTS' OBSERVATORY, BERKELEY, CAL.

BY BURT L. NEWKIRK.

This paper contains an investigation of the instrument, with a determination of corrections which must be applied to measures made with it. The method employed in measuring division errors of the scales is essentially the one employed by Gill for the scales of the Cape heliometer and Repsold measuring apparatus. Corrections are determined for each line of the X-scale and for seventy lines (from line 230 to line 300) of the Y-scale. The corrections are given to ten-thousandths of a millimeter and are accurate to within a few units of the last place.

The irregularities of the X-micrometer throughout three revolutions have been investigated and a table of the corresponding corrections determined by the method outlined in Brünnow's *Spherical Astronomy*, p. 426, fourth German edition. Two independent determinations yield results differing by about .0003 mm. in the maximum.

The straightness of the cylinder which determines the Y-axis and of the bar which determines the X-axis was also tested, as well as the perpendicularity of the directions of these two parts of the apparatus. The cylinder and bar were found to be very satisfactory and their directions are made perpendicular by adjustment.

The measurement of the distance between two well-defined points on a plate, first as a difference of X coordinates and then as a difference of Y coordinates, yields results differing by slightly more than the error of measurement, indicating that the Y-scale is not exactly parallel to the plate. The maladjustment in this particular would introduce an error into the measures that would in general be entirely negligible.

Tables are added for applying the necessary corrections to measured coordinates.

THE FORTY-FOOT CAMERA OF THE U. S. NAVAL OBSERVATORY ECLIPSE STATION AT GUELMA, AFRICA.

BY W. W. DINWIDDIE.

This instrument was mounted horizontally and the light was led to it by the mirror of a Gaertner cœlostat. Three ventilating doors were made in the lower side of the forty-foot tube, which, operated in connection with the trap doors in the roof of the building at the plate end of the tube, gave perfect ventilation and kept the whole instrument cool.

The shutter used in making the exposures during totality was placed in a nearly horizontal position above the mirror, and not between the lens and mirror, as is customary. The sunshade over the building and tube, and the wall of the tube, which was on the opposite side from the sunshade, were all whitewashed with ordinary lime. The sunshade was of opaque black cloth, and all the inner surfaces were black.

At the time of the eclipse eight exposures were made as follows: 2^s, $5^s.2$, $13^s.2$, $1^m28^s.1$, $38^s.3$, $6^s.8$, 5^s and an exposure of one-fourth second about ten seconds after third contact. All the negatives are sharp and clean. The unusual completeness of the series gives every part of the corona in fine detail on one or more of the plates. The first exposure shows a very large group of prominences. The short exposure made after the reappearance of the sun shows the entire ring of the corona. On this plate the prominences on the bright limb are shown in fine detail, and from it good measures may be made of the height of the chromosphere.

The first and fourth contacts were observed visually from the image on the face of the focal plane shutter, and recorded by a stop-watch. I think that this method of observing the outer contacts has advantages over the ordinary method of observing the limb with a small telescope. The times of the exposures were marked on the chronograph by a key operated by an assistant who looked after the cœlostat clock, set the mirror, etc.

The plates were thoroughly backed with water-color lampblack, which was carefully wiped off before development. Distilled water was used in developing and fixing, and after washing, the plates were rinsed in distilled water.

POLARIZED CORONAL LIGHT, AUGUST 30, 1905.

BY C. D. PERRINE.

Observations of polarized light in the corona were made by the Lick Observatory-Crocker Eclipse expedition to Alhama, Spain. A double-image prism was used in connection with a camera of twenty and three-fourths inches focal length, in continuation of the work at Sumatra in 1901.

More efficient apparatus was designed for the recent eclipse, and plane glass mirrors were used as analyzers. These cameras were of fifty inches focal length and yielded sharp images of good scale for photometric measurement. Strong radial polarization is shown on all the negatives.

ANOMALOUS REFRACTION.

BY FRANK SCHLESINGER AND C. B. BLAIR.

Under ordinary circumstances the atmosphere is disposed in horizontal strata of uniform density; but these strata may be inclined occasionally to the earth's surface giving rise to anomalous refraction.

In this case the usual expression for refraction should be replaced by a somewhat different one, deduced by the writer. The new formula has been applied to observations made in 1900 and 1901 at the six international latitude stations, with the object of discovering whether the effect of anomalous refraction is large enough to justify the frequent, but vague, appeals which have been made to this source of error in order to account for inconsistencies in meridian work. From this discussion it appears that observers have little to fear from this cause.

An important corollary to this conclusion relates to Kimura's recently discovered term in the latitude variation, independent of longitude. The present paper makes it highly probable that this phenomenon has a real existence and is not due, as has been suggested, to anomalous refraction.

NEW VARIABLE STARS IN THE SMALL MAGELLANIC CLOUDS.

BY HENRIETTA S. LEAVITT.

At the meeting of the Astronomical and Astrophysical Society held in Philadelphia in December, 1904, a brief account was given by the writer of methods and results in a study of faint variable stars recently undertaken at Harvard College Observatory. The most remarkable regions as yet examined are the Nebula of Orion and the two Magellanic clouds. These were mentioned a year ago, when it was reported that the numbers of variables in the large and the small Magellanic clouds were one hundred and fifty-two and fifty-seven, respectively. In the autumn of 1904, a series of sixteen plates was taken at Arequipa, covering the region of the small Magellanic cloud. These arrived at Cambridge in February and were examined with great interest, as it was expected that the number of variables would be considerably increased. The result of the examination, however, exceeded all anticipations. So many were found that it was April before the preliminary study of the plates was completed and it could be announced that nine hundred new variables had been discovered. The number has since been increased to nine hundred and seventy, and new ones are still being discovered from time to time. Measurements of the positions of all these, selection and measurement of a large number of sequences of comparison stars, and the determination of a provisional light-scale, have necessarily consumed much time, so that it has become possible to begin actual observation of the brightness of the variables. Light-curves thus far deduced are of well-defined types. Periods of many of the variables appear to range from one and a quarter to four days. A number, mainly among the brighter ones, have periods of from one to two weeks, while very few appear to have long periods. A preliminary examination of recent photographs of the large Magellanic cloud shows that it resembles the region now under discussion and it is probable that a very large number of variables will be found to exist within its limits. Preparations for measuring the positions and brightness of these are already being made.

The question as to whether there are other regions containing such remarkable groups of variable stars, is of the greatest interest. Not less important is the general problem of the distribution of these fainter variables. An exploration of new regions, therefore, is being undertaken as time permits, and even negative results, though less immediately interesting, are valuable as a contribution toward an ultimate solution of the problem.

AMHERST ECLIPSE EXPEDITION TO TRIPOLI, 1905.

BY DAVID TODD.

Instruments installed on the rigid roof-terrace of the British Consulate-General. Six departments of observation:

1. Observations of the geometric contacts.

2. Coronal photography with a twelve-inch Clacey lens of nine feet focus, photographically corrected. Eighteen exposures with semi-automatic movements. Baily's beads also photographed before second contact. My modified form of Burckhalter revolving occulter was employed on the corona. Corona photographed to 30′.

3. Duplex Clark lenses (photographic) of three inches aperture and eleven feet focal length, for long exposures on the circum-solar stars and the outer coronal streamers. No intra-mercurial planet revealed on 14 x 17 plates of the highest sensitiveness, stars to seventh and eighth magnitude.

4. A three-and-one-half-inch Goerz doublet of thirty-three and one-half inches focus, attached to one of the automatic movements used on my previous experitions of 1896, 1900 and 1901, secured

63 fine pictures of the corona during the 186 seconds of totality. Some of these show the coronal streamers to exceptional length.

5. Sketches of the corona with usual results.

6. Observations of shadow bands begun at least ten minutes prior to totality: bands wavering and narrow, moving swifter than one could walk, at right angles to the wind, their length with it, and waxing and waning five times during the interval of observation preceding totality. These observations communicated in detail to Mr. Lawrence Rotch of the Blue Hill Observatory.

THE PHILADELPHIA OBSERVATORY.

BY MONROE B. SNYDER.

The Philadelphia Observatory, an outgrowth of the old Central High School Observatory (1837-1900), was planned by the writer for an astrophysical observatory to begin with the Twentieth Century. The plan included a city station, chiefly for solar work and necessary popular instruction, and a suburban station, not yet realized, where certain lines of celestial photography could be undertaken. Peculiar difficulties delayed completion of the building and equipment, and there was a marked absence of financial and other support for the scientific work, so that not until early in 1905 was the really superb equipment, designed for both stations, received, and, as far as possible, erected at the city station in the new building of the Philadelphia Central High School.

On March 9, 1905, a destructive fire (probably originating in a combination gas and electric-light fixture), and long feared by the director of the observatory and others on account of municipal neglect of the usual fire precautions, swept the tower and destroyed an equipment and astronomical library valued at approximately $55,000, and produced a loss in equipment and building of more than $100,000. The equipment destroyed represented in a number of respects the very best attainable in instruments of moderate size, and included: A fifteen-inch refractor with Warner and Swasey mounting, the finest for its size, and provided with both a visual objective and a photographic objective of excellent definition, by Brashear; a Wadsworth-Hale spectroheliograph designed to photograph the sun in three different wave-lengths simultaneously; a large Keeler spectroscope and spectrograph, attached to the telescope on the day of the fire for the purpose of rediscovering (during maximum solar activity) Hale's disturbance in the sun's spectrum; a Warner and Swasey filar micrometer; a four-inch portable transit instrument with the writer's electrical transiter attached; clocks and chronographs (partially destroyed); a five-inch Rowland concave grating finely mounted by Brashear; a goodly equipped mechanical shop and photographic laboratory; and many smaller but valuable physical appliances.

The loss of a carefully selected library of some four thousand volumes representing the chief periodicals and literature in astronomy and astrophysics almost completed the destruction of years of effort. An eight-inch refractor and an unmounted set of Brashear eight-inch curved plate star cameras were rescued.

The main purpose, under the conditions of work hitherto allotted, was not only that the equipment should as a whole express the best current science, but that certain instruments like the spectroheliograph and its method of operating, the transiter, the new form of Hough printing chronograph, and the large curved plate star cameras should represent distinct advances in observatory equipment.

The observatory is in process of reconstruction.

ORBIT OF THE SEVENTH SATELLITE OF JUPITER.

BY R. T. CRAWFORD AND A. J. CHAMPREUX.

This paper gives results of an application of Leuschner's *Analytical Method of Determining the Orbits of New Satellites.* Three solutions were made which are designated in the tabulation given below by (Cr. & Ch.)$_1$, (Cr. & Ch.)$_2$ and (Cr. & Ch.)$_3$. The orbits are based on Perrine's positions of January 3, February 8 and March 6, 1905. The first set of elements was derived irrespective of any perturbations. The second represents the first approximation to elements osculating February 8 by taking immediate account of the attraction of the sun. The third set is the result of a close representation of the observations on the same basis. For comparison, the elements by Perrine (*Lick Observatory Bulletin,* No. 78) and by

ELEMENTS OF THE SEVENTH SATELLITE OF JUPITER (DIRECT MOTION) REFERRED TO THE EARTH'S EQUATOR.

Computer	Ω	i	ω	e	Period	a
(Cr. & Ch.)$_1$....	279° 45′ 8″	26°27′ 14″	006° 28′ 42″	0.12576	$251^{d}.1415$	49′ 48″
(Cr. & Ch)$_2$....	289 47 45	25 39 42	189 15 19	0.13195	255 .5376	50 20
(Cr. & Ch.)$_3$....	288 19 59	25 39 23	187 29 41	0.12152	258 .9424	50 47
Perrine (prel.) .	275 47	26 15	182 6	0.24	200	43 48
Ross (final)	281 7.8	26 12	331 16.8	0.0246	265 .0	52.54

a (Cr. & Ch.) for $\log(\rho) = 0.72124$; a (Ross) for $\log(\rho) = 0.71624$.

Ross (*Lick Observatory Bulletin*, No. 82) are also tabulated. The first set of elements does not represent an observation of August 9 any better than those of Ross. The third set, however, gives the residuals $(O - C)$:

$$\Delta p = + 2^\circ.7$$
$$\Delta s = + 5'.2$$

the computed positions being derived directly from the third set of elements osculating for February 8 without applying the solar perturbations February 8 to August 9. The solar perturbations are being computed for all observations secured since the discovery observations, by an adaptation of Encke's method of special perturbations in rectangular coordinates. With these perturbations it is expected to represent recent observations closely. Outstanding differences will serve to correct the third set of elements. With each of the three sets, a second solution with retrograde motion was obtained.

No abstracts are available for the following papers which were also presented at this meeting:

By C. L. POOR: The Figure of the Sun.

By N. E. GILBERT: Polarized Light in the Corona, Eclipse of 1905.

By C. C. TROWBRIDGE: Resemblances between Persistent Meteor Trains and the Afterglow from Electrodeless Discharges.

By G. C. COMSTOCK: A Proposed Method for the Wholesale Determination of Velocities in the Line of Sight.

By J. A. BRASHEAR: On Some Evidences of Permanent Set in Optical Surfaces.

By DAVID TODD: On the Practical Requisites for Securing Perfect Definition in Eclipse Photography.

By C. G. ABBOT: A Standard Pyrheliometer and its Use on Mt. Wilson, California. (Abstract in *Science*, XXIII., p. 203.)

By R. S. DUGAN: Magnitudes and Mean Positions of 359 Pleiades Stars.

EIGHTH MEETING

The eighth annual meeting of the Astronomical and Astrophysical Society of America was held on Thursday, Friday and Saturday, December 27-29, 1906, at Columbia University, in the City of New York, in affiliation with the American Association for the Advancement of Science. The total number of members in attendance was fifty-one. Thirty-two papers were presented. On Friday morning a joint session of the Society was held with the American Mathematical Society and with Section A of the American Association.

President Pickering, on taking the chair, discussed three lines of work which he believed the Society should pursue. First, by cooperation to carry out some great routine investigation too extensive to be undertaken by a single observatory. The best example of this was the accurate determination of the positions of the northern stars, by European and American observatories, under the direction of the Astronomische Gesellschaft. Second, to bring together socially astronomers from all parts of the country, especially the older and younger men. The latter may think the work of the older men out of date, but they may find the experience of the older men and their personal acquaintance with the eminent men of still earlier date of great assistance. The older men have much to learn regarding new methods, and the extensive appliances at their command may often be employed to much greater advantage if they keep themselves personally in touch with the most recent developments of astronomical research. Third, the presentation of papers. While hitherto this has been the principal function of this and other societies it is not necessarily the most valuable. General discussions are more interesting and instructive than long technical papers. It may, therefore, be wise to follow the example of some of the engineering societies, and print abstracts of papers for distribution some days before the meeting. A brief statement is made by the author of each paper, and the greater portion of the time is devoted to discussion. The ideal conditions for meetings of the Society would seem to be—a large hotel where all would eat and sleep under the same roof, and where the meetings could be held in the same building.

On the afternoon of December 28, a general discussion took place regarding neglected fields of work in astronomy, in which a large number of members took part, and the views expressed were varied and interesting. The president, in opening the discussion, cited a number of examples of fields of work, which seemed to him important but neglected. For example, in the astronomy of position, the formation of a standard catalogue of stars uniformly distributed, having similar spectra, and of nearly the same magnitude. Many troublesome sources of error, like those due to magnitude and color, would thus be eliminated. The variation of latitude should be studied at a series of southern stations like those now in operation in the northern hemisphere. The systematic search for double stars of the ninth magnitude and brighter, undertaken at the Lick Observatory, should be extended to the south pole. Photometric measures of faint stars, of comparison stars for faint variables, of the components of clusters, and of nebulæ are much needed. It is not known whether the spectra of nine-tenths of the nebulæ are gaseous or continuous. A wide field is opened in the study of the spectra of bright variables when faint, and of faint variables when bright, of the distribution of faint spectra and of the components of clusters.

The election resulted as follows:

President	Edward C. Pickering
First Vice-President	George E. Hale
Second Vice-President	William W. Campbell
Secretary	George C. Comstock
Treasurer	C. L. Doolittle
Councilors for 1907-9	Ormond Stone W. S. Eichelberger

The council designated Harold Jacoby to act as editor for 1907-8.

ABSTRACTS OF PAPERS

DISTRIBUTION OF DOUBLE STARS IN THE ZONE + 56° TO + 90°.

BY R. G. AITKEN.

The survey of the sky undertaken at the Lick Observatory to secure data for a statistical study of the number and distribution of double stars is well advanced, but the only large zone completely examined is the one from + 56° declination to the north pole. This region was divided into eight smaller zones, four of which were examined by Professor Hussey and four by the present writer. By counts of the stars on the charts, it appears that 12,299 stars 9.0 or brighter were examined in the region + 60° to + 90°. Of these, two hundred and ninety-four were known double stars and two hundred and fifty-nine more were found to be double, a total of five hundred and fifty-three pairs, all under five seconds except seven bright stars, giving a ratio of one double star to every 22¼ stars to 9.0 magnitude.

Tabulated by hours of right ascension and by zones four degrees wide, it was found that the distribution curve of these pairs closely resembles that of the stars to 9.0 magnitude in the same area, but that the double stars are *relatively more numerous in the richer sky areas.*

When only the pairs under two seconds or those under one second, or the very close pairs, or the brighter pairs, are considered, the same relation is found; as may be seen from the following table which groups the results by quadrants:

TABLE: ZONE + 60° TO + 90°.

Double Stars.	0 h. to 6 h.		6h. to 12 h.		12 h. to 18 h.		18 h. to 24 h.	
	No.	Ratio.	No.	Ratio.	No.	Ratio.	No.	Ratio.
Under 5″	173	1:19.4	87	1:28.6	86	1:30.2	207	1:18.7
Under 2″	113	1:30	56	1:44	66	1:39	132	1:29
Under 1″	76	1:44	37	1:67	40	1:65	80	1:48
Under 1/3″	15	1:224	9	1:276	11	1:236	24	1:161
7.5 Mag. or brighter	49	1:68	23	1:108	18	1:144	63	1:61
ZONE + 56° 9* + 60°.								
Under 5″	98	1:14.4	35	1:20.4	30	1:22.4	81	1:18.0

The zones north of 60° were examined with the twelve-inch telescope, but for fully one-half of the zone + 56° to + 60° the thirty-six-inch was used. In this zone 4257 stars of the ninth magnitude or brighter were examined and one hundred and thirty new double stars were added to the one hundred and fourteen previously known pairs, giving a ratio of one double star to 17.4 stars to the 9.0 magnitude. The table shows that the relations established in the area north of 60° hold true here also, though the ratio in the fourth quadrant is affected by the fact that in this quadrant the work was all done with the twelve-inch telescope. It is, therefore, safe to state that in this entire sky area the double stars are relatively as well as absolutely most numerous in the region richest in stars to the ninth magnitude, that is, in the region of the Milky Way . The study of local irregularities in the distribution, of which the charts give evidence, is reserved for a later paper.

THE VARIABLE RS PERSEI.

BY IDA WHITESIDE.

Three minima of this star observed this fall indicated a period of a little more than thirty-one days, through about two-thirds of which the star remained constant or very nearly so. This period also agreed very well with some scattered observations published in the *Astronomische Nachrichten,* and with others made at the Vassar College Observatory. At the time predicted for the fourth minimum the star failed to respond, going down very little if at all. It is probably irregular, but more observations are needed to confirm this statement. The range is only about a magnitude, from 8.2 to 9.2.

A SYSTEMATIC ERROR IN DISTANCE MEASURES OF CLOSE DOUBLE STARS.

BY W. H. PICKERING.

In 1900 a series of measures was made of the wide double star μ Draconis. Its components are nearly equal, and their distance is $2''.3$. The observations were executed with a five-inch telescope whose aperture could be reduced by a series of diaphragms to half an inch. A magnification of 300 was usually employed. It was found when the aperture was so small that the disks of the two components were in contact, or nearly so, that the distance between their centers was materially reduced. With an aperture of 0.6 inch the two centers coincided. Had they remained at their true distance apart, their combined image would have been appreciably elongated, instead of which it was perfectly circular.

It occurred to the writer to determine if the same effect was produced in the case of close double stars where large apertures were employed. A selection of suitable cases was made from Lewis's recent publication of measures of the Struve stars. It was found that the apertures employed by various observers could be divided into three classes, those of about eight inches, those of fifteen inches, and those of about thirty inches. When the separation was so slight that the star disks would have appeared in contact, or nearly so, with the smaller telescopes, it was found that the measures made with them were uniformly about ten per cent. too small. When the images were well separated the large and small telescopes gave identical results.

The early measures made on μ Draconis with the very small apertures indicate that the deviation is a real rather than a subjective one, and that the star images actually approach one another owing to some diffraction phenomenon. It would appear, therefore, that future catalogues of close double stars should always give the reader an opportunity of knowing the aperture employed with every observation. A more detailed account of this investigation will shortly appear in the *Harvard Annals,* Vol. 61.

THE TENTH SATELLITE OF SATURN.

BY W. H. PICKERING.

The elements of the orbit of the tenth satellite of Saturn, recently published (*Harvard Annals,* Vol. 53), were based on negatives taken at Arequipa in 1904. An examination of another set of negatives taken in 1900 has just been completed. The satellite was found upon them also, but some of the elements of its orbit differ materially from those found in 1904. This is particularly true of the eccentricity and the inclination. The orbit of 1904 was extremely eccentric, and it was noted in the publication above mentioned that in one part the satellite would pass extremely near to Titan. It was further suggested that the peculiarities of the orbit might be due to such a recent encounter.

The orbit of 1900 was found to be nearly circular, at times passing near Hyperion, however. It was not possible to tell from the negatives just when or how the elements had been transformed from those of one orbit to those of the other, if such a transformation had indeed taken place, but it seemed at least as probable as that two satellites should exist with practically the same period. The orbit is still under investigation, and later results will be published in the *Harvard Annals,* Vol. 61.

PHOTOGRAPHIC COLOR PHOTOMETRY OF SHORT PERIOD VARIABLE STARS.

BY J. A. PARKHURST AND F. C. JORDAN.

The broad problem of astronomical color photometry finds an interesting application in the determination of color changes in short period variables of the δ Cephei type. Various observers, by indirect methods, have found that these variables show stronger color at minimum than at maximum. As the spectroscope shows these stars to be binaries, a proof of color change coincident with light-variation would be of the highest importance. A direct determination of such changes is made possible by a suitable combination of color-filter, orthochromatic plate and reflecting telescope. An exposure on an ordinary plate (Seed 27) was followed immediately by one with a filter and Cramer 'Trichromatic' plate, which give visual magnitudes (as described by R. J. Wallace in the *Astrophysical Journal* for November, 1906). The two principal advantages of the method are: (1) the simultaneous determination of the visual and photographic magnitudes; (2) elimination of personal equation with its physiological complications, from the visual magnitudes of the colored stars, and the substitution of the peculiarities of the instrumental outfit, which can be definitely stated and exactly reproduced.

Briefly stated, the results confirm the color-changes in the short period variables under observation, the photographic range being greater than the visual; in other words, the color-factor (photographic *minus* visual magnitude) is greater at minimum than at maximum. Three stars will illustrate the results obtained.

X CYGNI

	Visual	Photographic	Color Factor
Maximum	6.28 Mag.	7.25 Mag.	0.97 Mag.
Minimum	7.15	8.75	1.60
Range	0.87	1.50	0.63
T VULPECULAE			
Maximum	5.50	6.05	0.55
Minimum	6.10	6.90	0.80
Range	0.60	0.85	0.25
S SAGITTAE			
Maximum	5.33	5.85	0.52
Minimum	5.95	6.93	0.98
Range	0.62	1.08	0.46

We have then the following results:

1. Binary systems, showing orbital revolution.
2. Colored stars, pointing to atmospheric absorption.
3. A regular variation in that color (*i. e.*, that absorption).

STANDARD PHOTOGRAPHIC MAGNITUDES.

BY EDWARD C. PICKERING.

(By title).

ON THE PROBABLE DISTANCE OF ORION.

BY HENRY NORRIS RUSSELL.

Almost all the bright stars in Orion are similar in spectrum and proper motion, and are probably at roughly equal distances from us. Their very small proper motions indicate that their parallax is too small to be directly measured, and Gill's observations of β Orionis confirm this view.

But many of these stars are double, and some appear to be physical systems showing more or less motion—always very slow. It is possible to derive a relation between the parallax and mass of such systems and the observed distance and rate of motion, which, though not exact in any one case, give good mean values when applied to several stars. Tests of this relation on forty well-known binaries show that its probable error for a single case is about twenty per cent. Applying it to nineteen pairs which appear to belong to the Orion group, and to be physical systems, we find for their mean parallax $\pi = 0''.011/\sqrt[3]{m}$, where m is their average mass, and π is subject to considerable uncertainty owing to errors of observation.

There are many spectroscopic binaries in Orion, but orbits have been published for only two. These indicate that the average mass of these stars is about ten times that of the sun, (subject to revision when more data are available). This leads to a mean parallax of $0''.005$ or a distance of about 600 light years.

For reasons already mentioned, this should be regarded only as an indication of the order of magnitude of the true distance. Errors of observation, and also errors of judgment in including as physical systems pairs which may ultimately turn out to be optical, would both tend to make the calculated parallax too great.

THE NUMBER AND DISTRIBUTION OF STELLAR CLUSTERS AND NEBULAE.

BY S. I. BAILEY.

The visible universe beyond our solar system is made up of two classes of objects, stars and nebulae. All star clusters may be divided into two classes, irregular and globular; the Pleiades serve to represent the former, and the cluster in Hercules, the latter. The term nebulae may be applied to any nebulous object, whatever its real nature, which can not be resolved into stars. All nebulae may be divided conveniently into two classes, gaseous and white, the former giving a spectrum of bright lines, the latter an apparently continuous spectrum. The best known example of the former is the great nebula in Orion, of the latter, the great spiral in Andromeda.

Somewhat less than seven hundred resolvable star clusters are known in the whole sky. Less than six hundred of these are irregular; nearly all are in or near the Milky Way, of which they form an intimate part, as has long been known. More than one hundred globular clusters are known, the distribution of which bears no relation whatever to the Milky Way, although a rich group of such clusters is found in the Milky Way. This appears to be an accident, however, since they do not seek the lines of greatest luminosity. This peculiar distribution of the globular clusters does not seem to have been pointed out before. Discovery of irregular clusters has been practically exhausted by small telescopes, since powerful photographic instruments reveal few new ones. It is probable, however, that the number of known globular clusters will be considerably increased among the so-called nebulous stars.

About 12,000 nebulae are now known. The whole number in the sky, however, is several times, perhaps many times, greater. The white nebulae are distributed in cloud-like groups over the sky, avoiding, in general, the Milky Way. The gaseous nebulae occur probably over the whole sky, perhaps in greater numbers in the Milky Way where the most striking objects of this class are found. The gaseous nebulae are probably few in number compared with the white nebulae.

The majority of all nebulae are spiral, but there are large numbers of nebulous stars, many of which may be faint globular clusters. The relation between spiral nebulae and globular clusters may prove to be more intimate than is now apparent.

THE NEBULOUS REGIONS OF THE MILKY WAY.

BY E. E. BARNARD.

This paper deals with some peculiarities of the nebulosities in the Milky Way. Though in some cases there seems to be every evidence that the stars and nebulosities are freely mixed together, still peculiarities of distribution, etc., show that with few exceptions (such as ρ Ophiuchi) the nebulosity does not indicate any tendency to condense about the stars. This is especially striking in the case of the great North America Nebula (so named by Dr. Max Wolf), where to all appearances the stars seem to exist in a vast bed of nebulous matter with no condensation about them individually. In this particular case the identity of the details of the nebula and the groupings of the stars seem to be conclusive proof that the nebula and the stars, apparently in it, really occupy the same part of space. Even in the case of that remarkable combination of nebulosity and stars, M 8, the stars seem freely mixed with the nebulosity, but in no case to be centers of condensation. Contrary to this condition, the great nebula of ρ Ophiuchi has condensations about the principal stars in that region, including σ Scorpii.

A photograph shows the singular nebulosities about γ Cygni, where a profusion of curved sheets and wreaths of nebulous matter cover a large part of the sky about the star and extend as far south as χ Cygni. A photograph of the nebula about ν Scorpii seems to show quite distinctly an obscuration of the light of the stars in that region. Where this remarkable object veils the sky, the stars seem to have decreased in magnitude. It gives the impression that the brighter stars in this region are dimmed and the fainter ones blotted out, as if produced by a thin obscuring veil of nebulosity this side of the small stars. This peculiarity is very strikingly brought out by the photograph.

In *Astronomische Nachrichten* No. 3111, Bd. 130, the writer has given an account, with a sketch, of a group of small nebulous stars

$$(1860\ \alpha = 18^h\ 2^m \pm;\ \delta = +\ 23^\circ\ 52' \pm),$$

which lies about 1½° following M 8. When these nebulous stars were examined with the twelve-inch telescope of the Lick Observatory in 1892, no connecting nebulosity could be seen. It was noticed, however, in a photograph made with the Willard lens that a nebulous wisp ran toward the group from M 8. The photographs made by the writer with the ten-inch Bruce telescope of the Yerkes Observatory at Mount Wilson in the summer of 1905 show that in this group the nebulous stars are simply condensations in a large irregular mass of nebulosity which extends to and connects with M 8.

APEX OF THE SOLAR MOTION.

BY GEORGE C. COMSTOCK.

It is well known that different astronomers have reached discordant results in seeking to determine the direction of the sun's motion through space. It is the purpose of this paper to present graphically (lantern projection) these several results classified with respect to the average brightness of the stars employed in the determination. When thus classified all determinations indicate a solar motion toward the north edge of the Milky Way, and the discordances in galactic latitude are not great. In galactic longitude, however, there is a well-marked dependence of the position of the apex upon the mean magnitude of the stars with reference to which it is determined. The stars of the tenth magnitude place this apex some 40° farther east than do stars of the third and fourth magnitudes, while intermediate magnitudes furnish intermediate positions. This variation is attributed to a small drift of the nearer stars in the plane of the galaxy and toward the constellation Cassiopeia. This is shared by most of the sun's stellar neighbors and affects the bright stars in larger measure than the faint ones because a larger percentage of the bright stars are included in this drift.

A COMPARISON STUDY OF BRIGHT CLUSTERS AND NEBULAE.

BY S. I. BAILEY.

FIELD EXPERIENCE WITH TRANSIT MICROMETERS.

BY JOHN F. HAYFORD.

SPECTROSCOPIC OBSERVATIONS OF STARS.

BY EDWIN B. FROST.

Nine Spectroscopic binaries were recently discovered with the Bruce spectrograph of the Yerkes Observatory, viz., RZ Cassiopeiae, X Cygni, 13 Ceti, ω Leonis, 85 Pegasi, τ^5 Eridani, τ^8 Eridani, τ Orionis, ξ^1 Canis Majoris.

THE CENTRAL ECLIPSE OF APRIL 13, 1912.

BY DAVID TODD AND R. H. BAKER.

Although the land totality of this eclipse will be visible for a few seconds only, it is desirable to prepare for observations. The central line extends from Oporto, Portugal, to Oviedo, Spain, the line of subsequent annularity passing close to Paris. These points are given by a definitive calculation of the track, made possible by the courtesy of Professor W. S. Harshman, U. S. Navy, Director of the Nautical Almanac, who forwarded in advance the necessary solar and lunar data which will be embodied in the American

Ephemeris for 1912. The change from total phase to annular takes place in the Bay of Biscay, according to the accepted diameters of the sun and moon; and it will be well to repeat the computation with slightly varying values. The application of photographic apparatus, operated automatically, may make it possible to obtain a useful and permanent record of this brief totality.

RELATION BETWEEN STELLAR SPECTRAL TYPES AND THE INTENSITIES OF CERTAIN LINES IN THE SPECTRA.

BY SEBASTIAN ALBRECHT.

In connection with the measurement of spectrograms obtained at the Mills Observatory in Chile by Professor Wright, an investigation of the individual spectrum lines was begun, with a view to determining whether there is a shift of any lines which is progressive from spectral type to type. Several lines were found to undergo such a progressive change, as is indicated by the radial velocities obtained from them. An examination of Rowland's tables shows that in most cases, lines apparently single are in reality blends of two or more close components. The nature of the variations is such as to indicate varying intensities of the same components rather than the presence or absence of different components in the different types. The investigation was limited to types F to Mb inclusive on the Harvard classification. In this classification the sun is of type G.

A comparison with Adams's list of sun-spot lines gives strong indications that the physical conditions in the stars as we pass from F to the Mb type vary in the same direction as from the sun to the sun-spots.

It was thought possible that for variable stars of large light changes, traces of velocity variations for some of the lines might be found, corresponding to small changes in spectral type as the stars varied from maxima to minima, and *vice versa.* In the case of o Ceti actual changes in the character of the spectrum are well established, though up to the present no appreciable changes in the wave lengths of any of its spectrum lines have been observed, leaving out of account the large displacements of the bright hydrogen lines. A comparison of the measures of η Aquilae, a variable star of the fourth class with a range of only 0.8 of a magnitude in light variations, showed evidences of variations in the positions of some lines from light maximum to minimum similar to the variations that were found from type to type. A further study of this variable star is desirable to establish definitely the exact character and amount of these variations.

These variations in the wave lengths of some of the lines depending on spectral type, will make necessary the exercise of great care in the selection of lines in radial velocity determinations, and a proper allowance for the type.

A DEVICE FOR ELIMINATING GUIDING ERROR FROM PHOTOGRAPHIC DETERMINATIONS OF STELLAR PARALLAX.

BY FRANK SCHLESINGER.

Experience has shown that a fruitful source of error in photographic work is what has been aptly termed the "guiding error." This arises from the fact that when the guiding is imperfect, the image of each star wanders from its mean position and these excursions are registered upon the photographic film to a different extent for stars of different brightness. This error is particularly troublesome in parallax work where the star under examination is usually much brighter than the comparison stars. After considerable experimenting the writer adopted the following simple device that seems to overcome the difficulty in a very satisfactory way. A rotating disk was mounted a little below the center of the photographic plate and about ten millimeters in front of it; that is, on the side toward the objective. The disk was made in two halves moving on the same axis, so that the opening left between their edges could be adjusted to any desired angle. The image of the bright star having been brought to the center of the plate and the disk set in motion, a part of the star's light will be occulted in each rotation of the disk. The amount of light that reaches the plate depends only upon the angular opening between the two halves of the slit and neither upon the rate at which they are revolving nor the distance of the image from the center of rotation. The images obtained in this way were free from any trace of diffraction caused by the edges of the disk-opening and were otherwise indistinguishable from images of fainter stars taken without the occulter. In parallax work the opening of the disk should be so adjusted that the apparent magnitude of the star under examination is about equal to the mean of the magnitudes of the comparison stars. The effect of guiding error will, therefore, almost entirely disappear. Actual measures upon plates taken with this device fully confirm this last statement.

PHOTOGRAPHIC OBSERVATIONS OF GIACOBINI'S COMET.

BY E. E. BARNARD.

These photographs show the almost sudden development of the tail between December 25 and 29, 1905, from a scant trace to a splendidly developed tail. A comparison with a photograph, made by Mr. Duncan at the Lowell Observatory on December 26, limited the time of development to less than three days. The tail underwent remarkable changes from day to day, but through interference from cloudy weather it was not possible with the one set of photographs to distinguish identical features on different dates, even though they existed, to determine the velocity of the tail producing particles.

ON THE DISTORTIONS OF PHOTOGRAPHIC FILMS.

BY FRANK SCHLESINGER.

The question as to the amount of distortion that a photographic film suffers during development is not yet settled. The method employed in the present paper is free from some assumptions that have hitherto been made and gives the average amount of the distortions independent of other sources of error. A plate was exposed to the sky and developed and dried in the usual way. It was then measured independently by two observers. Let us call these measurements A' and B'. The plate was soaked in water and then dried. It was now inserted in the measuring engine in, as nearly as possible, (within 0.01 mm.), the same position it had occupied and measured a second time by each observer. Instrumental errors were thus eliminated. Call these second measures A'' and B''. Then if e represents the *mean value* of the distortion (in a sense analogous to mean error) and if e_1 and e_2 are the mean errors of bisection for the two observers, then by appropriate subtractions we obtain

$$[(A'-A'')^2] = [e^2] - 2\,[e_1^2],$$
$$[(B'-B'')^2] = [e^2] - 2\,[e_1^2].$$

If we subtract each of the differences $(B'-B'')$ from the corresponding $(A'-A'')$ the result is free from the effect of distortion and we have

$$[((A'-A'')-(B'-B''))^2] = 2\,[e_1^2] - 2\,[e_2^2].$$

These three equations enable us to evaluate e as well as e_1 and e_2. Three plates, each with about sixty star images, were treated in this way and gave ± .0008 mm., ± .0006 mm., and ± .0003 mm., respectively, for the mean value of the distortion of the film. The experiment was varied and improved by spattering an undeveloped film with ink and measuring the small and perfectly round dots that were thus obtained, before and after the plate had been cleared in hypo, and thoroughly washed and dried. Five plates treated in this way gave, respectively, ± .0006 mm., ± .0006 mm., ± .0014 mm., ± .0015 mm., and ± .0015 mm. These experiments indicate that the distortions of the films are considerably less than inevitable errors like those of bisection, guiding errors, etc. If this conclusion should be confirmed by other observers it must have an important bearing on methods for measuring and reducing plates, since it would follow that elaborate precautions, such as have sometimes been employed for guarding against these distortions, are unnecessary.

DISTORTIONS OF PHOTOGRAPHIC FILMS ON GLASS.

BY SEBASTIAN ALBRECHT.

In the winter of 1904 an investigation of the distortions of photographic films on glass plates was undertaken by the writer at the suggestion of Director Campbell and Dr. Perrine. A preliminary investigation showed that if ordinary good care is taken in the treatment of the plate during development, fixing, hardening, washing and drying, there will be no general distortions, *i. e.*, no distortions extending over a large area of the film. Accordingly, the work was continued by a method which would more readily determine the character of local distortions. Photographs of spectra with numerous lines of different widths are very well suited for this purpose. These spectrograms showed that there were local distortions. These distortions were confined in each case to one or a few adjacent spectrum lines, and very rarely covered an area as much as 0.25 mm. square. The displacements of individual points in the distorted area occasionally amounted to 0.02 mm., which on the Crossley star photographs is equivalent to about one second of arc, and on the spectrograms taken with the one-prism spectrograph of the Lick Observatory to a radial velocity of about eighty kilometers per second for the $H\gamma$ region. Such large displacements as these are, however, extremely rare.

The distortions seemed to be of two different kinds: one caused by an actual movement of portions of the film, and the other by a displacement of the image apparently due to local differences in the sensitiveness of the film. Some of the characteristic shapes of the distorted lines due to the first cause were: a sine curve, a question mark, an irregular crinkle, an abrupt bend, a gradual bend which was sometimes shared by two and occasionally by three lines, while the lines immediately on either side of the distorted ones were perfectly straight.

The structure and chemical composition of the film are materially altered in the process of development and fixing, so that the strains produced in the subsequent drying need not be exactly the same everywhere in the film as they were before development. In fact, slight local readjustments might be expected, and it is remarkable that the resulting movements in the film should be so few in number, and be confined to such minute areas.

A RIEFLER CLOCK AND A SELF-REGISTERING RIGHT ASCENSION MICROMETER.

BY W. S. EICHELBERGER.

In September, 1903, there was installed at the U. S. Naval Observatory one of Riefler's sidereal clocks, No. 70, with nickel-steel pendulum and mounted in an air-tight glass case. At the same time the following scheme of observing was undertaken with the nine-inch transit circle; one astronomer would observe fundamental and miscellaneous stars for about two hours before sunrise, would observe the day planets and the sun, and would finish his tour of duty with another two hours' star observing just after sunset; a second observer would then commence and do star work for about six hours; and then a third man would observe a list of stars for about two hours before sunrise. Thus there were frequently three clock corrections determined during the same night by three different observers. Each night from September, 1903, to August, 1904, on which two or three men observed, has been utilized for determinating the relative personal equations of the various observers. This interval was divided men observed, has been utilized for determining the relative personal equation was obtained for each of these shorter intervals with the following results:

1903	E–L	E–R	E–B	E–M
Sept. 5 to Oct. 5	$+0^{s}.210$	$+0^{s}.051$		
Oct. 12 to Nov. 13	$+0.195$	$+0.048$	$+0^{s}.188$	
1904				
Jan. 30 to Mar. 29		$+0.056$	$+0.139$	$+0^{s}.062$
Apr. 3 to May 13		$+0.052$	$+0.119$	$+0.055$
May 24 to Aug. 15			$+0.112$	$+0.019$
Weighted Mean	$+0.205$	$+0.052$	$+0.133$	$+0.047$

The average probable error of one of these individual determinations is $0^s.009$.

All the men except M had observed with a transit circle some years before the observations here discussed were begun, yet with one pair of experienced observers there is quite a decided change in the relative personal equation within a few months.

For the same periods and the same pairs of observers the following differences between the largest and the smallest value for a single night were obtained:

1903	E–L	E–R	E–B	E–M
Sept. 5 to Oct. 5	$0^s.072$	$0^s.053$		
Oct. 12 to Nov. 13	0 .083	0 .050	$0^s.069$	
1904				
Jan. 30 to Mar. 29		0 .067	0 .128	$0^s.137$
Apr. 3 to May 13		0 .090	0 .094	0 .040
May 24 to Aug. 15			0 .140	0 .075

The general mean of all these numbers is $0^s.085$.

In attempting to adopt a mean clock correction for the entire night and to test the irregularity of running of the clock from day to day, this number is certainly large enough to be annoying. If it is due to irregularities in the running of the clock during the night, a new clock is needed. If it is inherent in the old key method of observing transits, something should be done to improve the method.

To test the clock for periodic daily irregularity another Riefler clock, No. 82, was compared with it every morning and afternoon and frequently twice during the night from January 19 to February 2, 1906, and a second time from February 23 to March 9. Between these two periods Riefler No. 70 was dismounted, cleaned and set up again. The probabilty that any periodic irregularity that might exist in these two clocks would be in the same phase in both series of comparisons is not very large.

The relative daily rate of the two clocks was in the first period

$$0^s.1426 + 0^s.00052\ t$$

and in the second

$$0^s.0298 + 0^s.00032\ t.$$

The residuals arising from the comparison of the observed and computed differences between the two clocks were then grouped with respect to the tenth of the day at which the clock comparison was made with the following results:

JANUARY 19 TO FEBRUARY 2, 1906

Decimal of a Day	No. of Comp.	Mean Residual	
.0	—	—	
.1	13	$+0^{s}.004$	$+0^{s}.005$
.2	2	$+0\ .008$	
.3	1	$+0\ .011$	$-0\ .001$
.4	7	$0\ .000$	
.5	2	$-0\ .014$	
.6	5	$+0\ .001$	
.7	—	—	$-\ \ .005$
.8	1	$+0\ .008$	
.9	11	$-0\ .006$	

FEBRUARY 23 TO MARCH 9

Decimal of a Day	No. of Comp.	Mean Residual	
.0	—	—	
.1	15	$0^{s}.000$	$0^{s}.000$
.2	—	—	
.3	6	$+0\ .002$	$0\ .000$
.4	7	$0\ .000$	
.5	—	—	
.6	4	$-0\ .006$	
.7	—	—	
.8	—	—	
.9	14	$0\ .000$	$0\ .000$

Of the 88 separate residuals three-quarters are less than $0^{s}.01$ each, a quantity that I had supposed less than the uncertainty with which a clock comparison was read from the chronograph sheet.

At the end of October, 1906, the six-inch transit circle was equipped with a self-registering right ascension micrometer of the Repsold type made by Warner and Swasey.

Previous to beginning the following series of observations, one of the observers had practiced with the new micrometer on two nights and the other two on one night each. Two men worked on each of the eight nights, each observing ten time stars. Each man on half of the nights that he worked observed the first list of ten stars, and on the remaining nights the second list. The same twenty stars were used throughout the entire series.

A least-square solution gives for the relative personal equation

$$E - F = +\ 0^{s}.001 \pm 0^{s}.012$$

and

$$E - L = -\ 0^{s}.001 \pm 0^{s}.015.$$

The relative personal equation $E - L$ by the key method of observing was $+\ 0^{s}.20$.

The clock rates during these six weeks were also computed by least squares, first giving a weight unity to each rate and, second, a weight equal to the interval between the observations from which it was determined.

The resulting rates are

$$-0^s.0436 + 0^s.000924(T - \text{Nov. } 25.0)$$

and

$$-0^s.0445 + 0^s.000997(T - \text{Nov. } 25.0),$$

giving as residuals:

$O - C$	Weight	$O - C$	Weight
—0.011	1	—0.009	8
+0.015	1	+0.017	5
+0.010	1	+0.012	1
—0.023	1	—0.022	2
+0.011	1	+0.012	4
—0.001		0.000	13
—0.003		—0.002	7
±0.011		±0.007	

A similar discussion of rates obtained by the key method of observing transits gave for thirteen weeks in the spring of 1904 a mean residual of $0^s.015$.

We thus see that by the use of the self-registering right ascension micrometer in this series of observations the mean residual of the daily clock corrections is decreased from twenty-five to fifty per cent. and relative personal equation has disappeared.

A NEW FORM OF MERIDIAN MARK.

BY G. W. HOUGH.

Two years ago I established a meridian mark in order to study the change of azimuth for the 6⅜-inch Repsold meridian circle. Collimator marks, according to published statistics, as well as from theory, do not seem to be sufficiently stable for the study of azimuth changes unless supplemented by frequent observations of circumpolar stars. The method I have employed for bringing a mark in focus is simple, direct and vastly preferable to the use of a long focus lens; since the marks may be located at such distance that any probable change in the place of the pin will not sensibly change the direction.

In photographic work, when it is desired to bring objects lying in different planes to a common focus, the aperture of the lens is reduced. Accordingly, I made some experiments and found when the aperture of the object glass of the Repsold meridian circle, of 6-foot focus, was reduced to one inch, all objects at about one thousand feet and beyond were brought in good focus.

A concrete pier two feet square and rising two and one-half feet above the surface of the ground was erected at a distance of eleven hundred and forty feet. On the top of the pier was bolted a cast iron box, fifteen inches wide, ten inches high, and ten inches deep. Inside the box is an adjustable brass plate with a hole 0.15 of an inch in diameter, behind which is placed a 50-volt sixteen-candle power lamp. Electricity is supplied from a storage battery, at the Observatory, which had been installed for rotating the dome and illuminating the instruments. During daylight, when the sun is not shining, the mark appears like a sixth magnitude star; at night brighter.

In order that an object at a finite distance may suffer no change in direction, the hole in the cap which covers the object glass must be in the optical axis. Any deviation will cause a displacement proportional to the focal length of the telescope divided by the distance of the object. At one thousand feet one inch subtends an angle of 17″.1. Hence very great precision in the fit of the brass cap is unnecessary. In order to know whether the hole in the cap is in the optical axis, the cap may be revolved one hundred and eighty degrees, or the mark may be observed with the *full* aperture of the object glass. In the latter case there is seen a well-defined disk of light about 90″ in diameter.

In 1861 and for a number of years following, at the Dudley Observatory, I had a mark at a distance of six miles. After a rain the mark could be observed with great precision. The unsteadiness of a terrestrial mark does not depend directly on the distance.

THE SIGNIFICANCE OF THE STAR RATIO.

BY GEORGE C. COMSTOCK.

The number of visible stars increases very rapidly as we extend the count to fainter and fainter magnitudes, and any rational attempt at their enumeration must involve a limit, or limits, of brightness at which that enumeration shall cease. The rate of increase in the number of stars as this limit is made to move down the scale of magnitudes is called the star ratio, and the numerical value of this ratio in different parts of the sky and at different points of the scale of stellar magnitudes has been made the subject of research by many astronomers. From these investigations it appears that in general the number of stars is increased more than threefold and considerably less than fourfold for each increase of one magnitude in the limit to which the enumeration is extended. The ratio appears to be a little greater in the Milky Way than in the extra-galactic regions and possibly a little greater for the brighter magnitudes than for the fainter ones, although it seems probable that the last relation is confined to the region outside the Galaxy.

The point of major interest in the discussion is, however, that in general the rate of increase is decidedly less than fourfold, while a very simple analysis shows that if the stars are strewn with some rough uniformity of distribution throughout a region of indefinite extent, the average star ratio should be very approximately a fourfold increase per magnitude. The disparity between this theoretical ratio and that found actually to obtain, throws discredit upon the hypothesis above made with respect to the distribution of the stars, and there has been reared upon it the current concept which represents the stellar system as of finite and measurable extent, broader in the Galaxy because here the star ratio is relatively large, smaller at right angles to the Milky Way because here the star ratio diminishes. The idea is that the faint stars are faint because of their greater distance and are more numerous because of the volume of space in which they may be distributed increases with the cube of the distance. But if the stellar system reaches out only to a certain limit and the space beyond is void, it can contribute nothing to the number of stars and the star ratio, while everywhere below the value that would obtain for an infinite system ought to diminish very rapidly as we approach the confines and deal with stars fainter than any that have been hitherto enumerated, although Professor Pickering holds that even within the range of magnitudes covered by his investigations, such a diminution in the value of the ratio is distinctly shown.

The present paper controverts the views above outlined, and shows that the supposed fourfold ratio that constitutes their theoretical basis has been erroneously derived through ignoring an essential factor of the problem. The faint stars appear faint not only because of their greater distance, but because they actually emit less light than do the brighter ones, and because of this inferior luminosity they are nearer than has been assumed. This diminished distance is shown by observation of their proper motions and because of it we have a diminished space available for the faint stars, they are less numerous and the star ratio smaller than is required by the erroneous theory above considered. When the diminishing intrinsic brightness of the fainter stars is properly taken into account the author finds from a discussion of the star ratio for galactic stars down to the faintest yet enumerated (the Herschel gauges), that there is here no indication of a limit to the stellar system.

Outside the Galaxy the conditions are different, the values of the star ratio are progressively smaller and suggest some one of the following alternative conditions or possibly a combination of them:

(*a*) At right angles to the Galaxy the limits of the stellar system fall within the range of vision, as indicated above.

(*b*) The stars remote from the plane of the Galaxy are on the average progressively less luminous than those in the Galaxy.

(*c*) The transmission of light through the extra-galactic spaces is impeded by some absorbing medium which serves to diminish the brilliancy of the stars in larger measure than is the case in the Galaxy.

Any of these alternatives will serve in explanation of the observed facts and it is not now feasible to make definite choice among them.

PRELIMINARY WAVE-LENGTHS FROM FLASH SPECTRA TAKEN IN SPAIN, 1905.

BY S. A. MITCHELL.

The flash spectra were photographed by means of a Rowland four-inch grating ruled on a parabolic surface. The grating was used without a slit, so that the spectrograph consisted merely of grating and photographic plate. The spectra, which show wonderfully fine definition, extend from the D lines to λ 3300 in the violet, a distance of 9.5 inches.

Measurements are now being made on the three or four thousand lines of the flash spectra. These photographs show a dispersion about the same as the Bruce three-prism spectrograph of the Yerkes Observatory and the Mills spectrograph of the Lick Observatory, or a dispersion one-fifth that of a twenty-one-foot grating of ordinary Rowland mounting in the first order spectrum, or one-tenth of the second order. The eclipse spectra are practically normal. Wave lengths thus far deduced show a probable error less than five-hundredths of an Angström unit.

COMPARISON OF RESULTS OF OBSERVATIONS WITH THE REFLEX ZENITH TUBE AND ZENITH TELESCOPE AT THE FLOWER OBSERVATORY DURING 1905 AND 1906.

BY C. L. DOOLITTLE.

THE TEMPERATURE OF MARS.

BY PERCIVAL LOWELL.

ON THE ABSENCE OF LONG HEAT WAVES IN THE SUN'S SPECTRUM.

BY E. F. NICHOLS.

FORMULAS FOR THE COMPARISON OF ASTRONOMICAL PHOTOGRAPHS.

BY HAROLD JACOBY.

This paper contains formulas suitable for the direct comparison of rectangular coordinates measured on different astronomical negatives. The problem here involved supplements what may be called the fundamental transformations in the reduction of celestial photographs; viz., the calculation of right ascensions and declinations from rectangular coordinates, and rectangular coordinates from right ascensions and declinations.

LIGHT CURVES OF NEW VARIABLE STARS OF THE ALGOL TYPE, AND OF SHORT PERIOD.

BY HENRIETTA S. LEAVITT.

In a recent circular of the Harvard Observatory thirty-six variable stars were announced, mostly brighter than 9.5 at maximum. All are within fifteen degrees of R. A. 12^h, Dec. — 60°, the region including both the Southern Cross and the Nebula in Carina. About sixty new variables in this area, mostly fainter than the tenth magnitude at maximum, had been announced in previous circulars. A large proportion of the new objects appear to have short periods, and several are of the Algol type. These are now being studied with a view to determining their periods and light curves. The periods of four have already been announced, those of three others are now made public for the first time. All but one of the seven variables are of the Algol type. The periods vary from nine-tenths of a day, to five and one-third days, while the smallest and the largest ranges observed are four-tenths of a magnitude, and two and one-half magnitudes respectively.

The variable C.P.D.—50°3809 is of special interest, as the period is equally divided by a secondary minimum. The principal minimum is nine-tenths of a magnitude fainter than the normal brightness, 9.3, while the secondary minimum is four-tenths of a magnitude fainter than the normal. The average deviation from the light curve of a single observation is very large, being no less than ± 0.14 magnitude, while the average deviation for all other Algol variables here described, is only ± 0.07 magnitude. This large deviation does not appear to be due to accidental errors of observation, though the variable was difficult to measure on many of the plates. It has not been found possible to improve the period on the supposition that it is constant, and it is probably to be corrected by a third term, not yet determined.

C.P.D.—49°6972 has a large range. The faintest magnitude observed is 11.5, which is two and a half magnitudes fainter than the normal brightness; but no observations at minimum have as yet been secured, and the form of the light curve at that point is not determined.

C.P.D.—63°2485 was at first supposed to be of the Algol type, but has been found instead to be a short period variable of unusual interest. As has already been announced in a recent circular, the light curve resembles that of an Algol variable with a minimum covering about half the period, but the light appears to be changing continuously, though very slightly, even when near the maximum. As the range is only four-tenths of a magnitude, four independent observations were made on each plate. By taking means, the accidental errors were reduced one-half. The mean magnitudes were then arranged in the order of phase, and the mean phase and magnitude was taken for each successive group of five plates. The average deviation from the light curve of the points thus obtained is only ± 0.02 magnitude, and may be compared with the deviations found with the best photometric measures.

The large proportion of Algol variables among those discovered in this region is interesting. Of the thirty-six variables announced last month, four have already been shown to be of the Algol type, and others, of which the observations have not yet been discussed, are supposed to belong to the same class. On the other hand, of the more than seventy variables in Scorpius and Ophiuchus, announced two years ago, few, if any, appear to vary in this manner. The same is true of the Magellanic Clouds. The present study of the distribution of the variable stars is in a very early stage and much generalization from the results as yet obtained is rash. Yet it has already become evident that certain kinds of variables are apt to be found in groups. It is desirable that the number of persons engaged in this research should be increased, so that the systematic survey of the heavens may be completed with a reasonable degree of thoroughness during the next few years. Evidently it is of the highest importance to ascertain the types to which new variables belong, even if their number is too large to permit of the computation of all the periods.

A PECULIAR BINARY SYSTEM.

BY ERIC DOOLITTLE.

LATITUDE TERMS OF LONG PERIOD, FROM THE FLOWER OBSERVATIONS.

BY C. L. DOOLITTLE.

This series embraces a period of seven years and nearly two months, and is practically homogeneous in all respects. As a term having a period of about six years has been supposed to be indicated by similar series elsewhere, it seems desirable to examine my results for evidence on this point.

Without making any assumption as to the law of latitude variation, the intervals from minimum to minimum were found graphically. The maxima were not employed for this purpose, as they were less clearly indicated. Six periods were found as follows:

1st	459 days
2nd	410
3rd	470
4th	439
5th	446
6th	416
Mean	440 days

6 Julian years = 2191.5 days
5 periods = 2200 days

The difference of 8.5 days is of no importance for present purposes.

This close agreement seems to fall in line with the possible existence of a term having a period of about six years.

The method of procedure was as follows: For each interval from minimum to minimum, terms of the form $x \sin\theta + y\cos\theta$ were removed from the given values of the latitude. A series of 103 equations was then obtained of the following form:

$$\Delta + ax + y\sin\theta + z\cos\theta + u\sin 2\theta + v\cos 2\theta = n.$$

Δ is a constant correction to the latitude assumed; x a uniformly progressive change; and the period of θ is six years.

The solution results in the following expression for $\Delta\phi$ in units of the second decimal place:

$$-1.96\sin\theta + 0.35\cos\theta + 1.25\sin 2\theta + 0.94\cos 2\theta,$$

x is quite inappreciable.

The maximum and minimum values of this expression are as follows:

Maximum	1898, February 1,	$+0''.024$
Minimum	1902, April 9,	$-0\,.035$

The range, $0''.059$, seems too great to be altogether fictitious when the amount and character of the data employed are considered.

PERIOD OF SOLAR ROTATION.

BY PHILIP FOX.

An investigation of the solar rotation period based upon measurements of positions of sixteen hundred calcium flocculi on one hundred of the Rumford spectroheliograms taken at the Yerkes Observatory in the year 1904, gives the following results:

ϕ			ξ	P
0°	to	5°	14°.50	24ᵈ.82
5	to	10	14 .44	24 .93
10	to	15	14 .18	25 .38
15	to	20	13 .92	25 .86
20	to	25	13 .68	26 .32
25	to	30	13 .95	25 .80
30	to	35	13 .68	26 .31
35	to	40	13 .25	27 .18

The investigation will be continued, using the plates for the years 1905 and 1906.

OPPORTUNITIES FOR SOLAR RESEARCH.

BY GEORGE E. HALE.

It is safe to say that every astronomer would prize an opportunity to observe any of the fixed stars from a position where its disk would appear as large as the sun. It does not seem probable, however, that such observations of stellar phenomena can ever be made, except in the case of the sun itself. For it should ever be borne in mind, when considering the importance of solar research, that our most intimate knowledge of stellar phenomena must be derived from solar observations. In the case of the other stars, we may determine their positions, measure their radial velocities, observe their brightness and analyze their light, but we have no means of studying the details of their structure, which must be understood before we can advance far in the solution of the great problem of stellar development. Thus we are driven back to the sun and forced to the conclusion that this typical star well deserves our most serious attention, and the application of every available means of research.

One can not but be impressed, when considering the sun from this standpoint, with the comparative neglect of the numerous opportunities awaiting the student of solar physics. It is possible, by the application of easily available instruments, for any careful student, wherever situated, to solve solar problems of great importance. If time permitted, it could be shown that almost all the apparatus required in such work can be constructed at very small expense. For our present purpose, however, let us assume that the observer has at his disposal one of the cœlostats so commonly employed in eclipse work. If this cœlostat has a rather thick mirror, which is frequently resilvered, it may be depended upon to serve well for solar work, provided that the mirror is shielded from sunlight during the intervals between the exposures of photographs, and that these exposures are made as short as possible. We may assume that the sunlight is reflected from the cœlostat mirror to a second plane mirror (which should also be as thick as possible) and from this mirror to an objective, which should have an aperture of at least six inches and a focal length of from forty to sixty feet. In place of this objective, a concave mirror, of similar aperture and focal length, may be employed. This apparatus will furnish the necessary means of forming a fixed solar image, of large diameter, within a laboratory, where accessory apparatus can be mounted. Let us now consider briefly some of the investigations that can be undertaken.

Direct Photography.—The routine photographic work, done under the direction of the Greenwich Observatory, provides ample material for the study of the positions and motions of sun-spots, but special investigations may well be undertaken with the aid of direct photographs. The important thing in all solar work is not merely to make observations of some single phenomenon, but to carry on two or three series of carefully correlated observations, so designed as to throw light on one another. For example, Mr. Maunder has recently found that the rotation period of sun-spots in nearly the same latitude show differences as great as those encountered in passing from the equator to the highest latitude in which spots are found. The cause of such differences may well be a subject of the most careful investigation. The proper motions of spots, which are associated with their period of development, must be fully taken into account. We might also make the hypothesis, merely for the purpose of testing the question, that the rotation period of a sun-spot depends upon its level with respect to the photosphere. For this reason it would be desirable to investigate, in connection with the study of the rotation, the question of the level of sun-spots. A simple means of doing this will be mentioned later. But it may be added here that the question of level raises other conditions, which should not be left out of account. It is probably worth while to investigate photographically the old Wilsonian hypothesis, since visual observations have proved so discordant in attempts to determine the relative widths of the preceding and following penumbra of spots at various distances from the center of the sun. As a sun-spot is depressed below the level of the surrounding faculæ, the vexed question of the visibility of the umbra near the limb may depend upon whether faculæ are present or missing on the sides lying in the line of sight. It is quite possible that the temperature of the umbra may vary with its distance above the photosphere. Thus correlation between observations bearing on spot level and observations of spot spectra is desirable.

Spectroscopy.—The spectroscopic study of solar phenomena has been greatly retarded, through delay in adopting suitable instruments. The short-focus spectroscopes attached to equatorial telescopes are admirably adapted for visual observations, but in photography their linear dispersion is much too small to realize the full resolving power of the grating employed. In laboratory work, on the contrary, while spectroscopes have been sufficiently powerful, they have usually been of the concave grating type, where astigmatism interferes seriously with the study of solar details, and the solar image on the slit of the spectroscope has been so small that the individual phenomena, in any event, could not be separately distinguished.

The construction of a powerful spectrograph of the Littrow type is an extremely simple matter. A small slit, mounted on a short metallic tube, is supported immediately above a long narrow photographic plate. The wooden support for plate holder and slit rests on a pier and forms the end of a long light tube of rectangular section, which is closed at its other end by the wooden support for the lens, which serves at once for collimator and camera. The angular aperture of the lens is, of course, defined by that of the objective which forms the solar image on the slit, but if possible its focal length should be from ten to twenty feet. The rays, after being rendered parallel by the lens, fall upon a grating, which need not be larger than a four-inch (a much smaller one would do very useful work). The spectra should be photographed in the second, third, or fourth order, so as to give a sufficient scale.

With such an instrument, new work of great value may be done. Even with a very small solar image, a photographic study of the solar rotation should yield results of great precision. Halm believes, from his spectroscopic work, that the rotation period varies with the solar activity. This is yet to be confirmed, but the question well deserves investigation. There is some reason to think that the rotation period is not the same for different substances in the reversing layer. The iron lines, for example, may give values different from those obtained with the carbon lines. It is also interesting to inquire whether the enhanced lines of an element give the same period as the other lines in its spectrum.

Another interesting investigation, which does not require a large solar image, is the study of the radial velocity of the calcium vapor in the flocculi. It is only necessary to measure, with great precision, the wave lengths of the H_2 and H_3 lines, corresponding to various points on the solar image. In this way the rise and fall of the calcium vapor in the flocculi can be ascertained. To be of the most service, this investigation should be carried on in conjunction with some other study of the flocculi.

The photographic study of sun-spot spectra offers a most promising opportunity. It is a very easy matter to photograph spot spectra in such a way as to record for study thousands of lines which are beyond the reach of visual observation. Nevertheless, this has been accomplished only recently, simply because spectrographs of suitable design have not previously been applied in this work. At the Solar Observatory on Mount Wilson it has been found that, in general, the lines strengthened in spot spectra are strengthened in the laboratory when the temperature of the vapor is reduced, while the lines that are weakened in sun-spots are weakened in the laboratory under the same conditions. Thus it appears probable that the temperature of the spot vapor is below that of the reversing layer. This conclusion has been confirmed by the discovery in the spot spectrum of the flutings of titanium oxide. This compound thus exists at the lower temperature of the sun-spot, but is broken up into titanium and oxygen at the higher temperature of the reversing layer. The bearing of this result upon stellar spectroscopy will be seen when it is remembered that the flutings of titanium oxide form the principal feature of the spectrum of the third type stars. It has also been found that Arcturus gives a spectrum resembling very closely the spectrum of a sun-spot. A further study of this question will require a large number of observations of spot spectra, with special reference to the question of variations in temperature, as indicated by variations in the relative intensity of the spot lines. As already remarked, the temperature of spots may also depend upon their level, and this possibility must be borne in mind.

Work with the Spectroheliograph.—It is perhaps commonly supposed that the spectroheliograph is necessarily an expensive instrument, out of reach of the average observer. As a matter of fact, however, a spectroheliograph capable of giving the best results can easily be constructed of materials ordinarily available in any observatory or physical laboratory. It is sufficient, for many purposes, to photograph only a narrow zone of the solar image. In this case small lenses will suffice for the collimator and camera, and small prisms for the optical train. The lenses and prisms may be mounted in wooden supports, on a wooden platform, rolling on four steel balls in V-shaped tracks. The motion of the instrument across the solar image may easily be produced by a simple screw, driven by a small electric motor. Such a spectroheliograph was used to good purpose at the Solar Observatory before the permanent instrument was completed.

Brief mention may be made of some of the numerous investigations possible with such an instrument. It has recently been found at the Solar Observatory that the dark hydrogen flocculi, photographed near the sun's limb, are slightly displaced with reference to the corresponding calcium flocculi. In general, they lie nearer the limb. This probably indicates that the absorbing hydrogen clouds are, on the average, at a higher level than the brilliant calcium clouds. This subject deserves careful investigation, extending over a considerable portion of time. The type of spectroheliograph just referred to is as suitable for the purpose as any instrument that can be constructed. Another question, which seems to be somewhat more difficult to solve, is the actual difference in elevation of the calcium flocculi, as photographed in the H_1 and H_2 lines. Indeed, it is still a question as to how important a part the dense calcium vapor plays in determining the form of the H_1 flocculi. These objects resemble the faculæ so closely that they appear practically identical with them, though slight differences, which are apparently genuine, are occasionally found.

Another method of investigating this whole question of levels is afforded by the spectroheliograph. It will be remembered that when the level of sun-spots was last under discussion, reference was made to the relative radiation of the umbra and neighboring photosphere, corresponding to different distances from the center of the sun. It was pointed out that when a spot approaches the limb, its radiation decreases less rapidly than that of the photosphere. The natural conclusion was that the spot lies at a higher level than the photosphere and thereby escapes much of the absorption produced by a comparatively thin layer of absorbing matter. Recent observations at Mount Wilson have shown, however, that the proportion of violet light in sun-spots is much smaller than in the case of the photosphere. As it is known that the violet rays undergo much more absorption near the sun's limb than those of greater wave length, it is obvious that the light of the spot would suffer less absorption, even if it were at the same level as the photosphere. Thus the only proper method of investigating this question will be through the use of monochromatic light.

The spectroheliograph affords a simple means of accomplishing this. It is only necessary to make photographs of the spot and adjoining photosphere, corresponding to various distances from the sun's center. The camera slit should be set on the continuous spectrum (not on a line), preferably in the violet or ultra-violet, since change of absorption would be most felt in this region. In order to make photographic comparisons easily possible, the intensity of the photosphere should be reduced to approximately the intensity of the umbra, by means of a dark glass, mounted over the collimator slit, but not covering that part of the slit through which the light of the umbra passes. It is obvious that a large image of the sun will be required in this work.

The spectroheliograph can be applied to other studies of absorption. The H_1 flocculi, for example, are reduced in brightness near the sun's limb much more than the H_2 flocculi, presumably because the latter lie at a higher level. These differences can be studied photometrically on spectroheliograph plates made for the purpose.

Since it is a question just what level is represented by the background (between the flocculi) in calcium, hydrogen, or iron photographs, the instrument should be arranged so as to permit photometric comparisons with the light of the photosphere, of practically the same wave length as the calcium, hydrogen or iron line employed.

These new applications of the spectroheliograph have only recently occurred to me, and are mentioned because of their suitability for use with instruments containing prisms of ordinary height, capable of photographing only narrow zones of the solar image. Numerous other problems might be mentioned, such as the comparative study of H_1, H_2, and H_3 photographs, and of calcium, hydrogen, and iron images; the distribution of the flocculi in latitude and longitude, their varying area, as bearing on the solar activity and on terrestrial phenomena, and their motion in longitude, as measuring the solar rotation. But limitations of time forbid more than a mere reference to work and methods, the details of which are discussed elsewhere. My purpose has been accomplished if I have shown that with comparatively simple instrumental means any careful observer may secure important results. In much of this work it is desirable that investigators occupied with similar problems should cooperate with one another. The International Union for the Cooperation in Solar Research was organized with this end in view. It has already inaugurated solar studies, on a common plan, in several different fields, and is preparing to extend the range of its activities in the near future.

NINTH MEETING

The ninth annual meeting of the Society was held at Hotel Victory, Put-in-Bay, Ohio, on Tuesday, Wednesday, Thursday and Friday, August 25-28, 1908. In welcoming the Society to Put-in-Bay, President Pickering referred to the considerations which had influenced the Council in the selection of this place for the meeting. It had been the desire that a meeting be held where the members could be together between the sessions as well as at them, under circumstances which would enable them to become better acquainted and at the same time afford opportunity for the discussion of matters of mutual interest. It was thought that this might best be accomplished by holding the meeting at a large hotel, far removed from city influences, where all would eat and sleep under the same roof and where the sessions could be held in the same building. These conditions were satisfied at Hotel Victory, which stands in large and pleasant grounds, upon an island in the midst of Lake Erie.

The meeting was attended by twenty-nine persons. At the last session officers were elected as follows:

President	E. C. Pickering
First Vice-President	George C. Comstock
Second Vice-President	W. W. Campbell
Secretary	W. J. Hussey
Treasurer	C. L. Doolittle
Councilors for two years	W. J. Humphreys Frank Schlesinger

Professors Harold Jacoby and F. H. Seares were designated as the editors for the meeting.

ABSTRACTS OF PAPERS

FORMULAS FOR THE REDUCTION OF SATELLITE OBSERVATIONS.

BY ASAPH HALL, JR.

Professor Hall referred to the satellite observations which he was making with the twenty-six-inch refractor of the U. S. Naval Observatory, and presented the formulas which were being used in their reduction. These were based upon Bessel's formulas.

DOOLITTLE'S MEASURES OF THE HOUGH DOUBLE STARS.

BY G. W. HOUGH.

In this paper the author expresses his great obligations to Professor Eric Doolittle for undertaking and carrying out in a thorough manner so extensive a piece of work as the remeasurement of all the double stars discovered by him, and upon the basis of this work he classifies the double stars contained in this catalogue, with respect to their distances, as follows:

Distance	No. of Pairs
Under 0″.5	84
0″.5 to 1″	74
1″ to 2″	101
2″ to 5″	172
Over 5″	218

This catalogue is notable for the large number of close pairs that it contains. Special mention is made of Ho. 212 = 13 Ceti, the second most rapid telescopic binary at present known. Its period has been established largely through the continuity of measures made by Professor Aitken at the Lick Observatory, according to whose elements it completes a revolution in 7.35 years. Professor Doolittle gets practically the same result, 7.42 years.

THE STANDARD CLOCK OF THE U. S. NAVAL OBSERVATORY.

BY W. S. EICHELBERGER.

In December, 1906, in an address before the American Association for the Advancement of Science (*Science*, March 22, 1907, p. 451), I presented a table showing the daily rates of the standard clock of the U. S. Naval Observatory, Riefler Sideral Clock No. 70, from February 8 to May 12, 1904.

This clock was enclosed in an air-tight glass case and was mounted in a vault where the temperature was artificially controlled. However, during the period mentioned it was found impossible to prevent air from leaking into the case so that a nearly uniform pressure was maintained by pumping out one or two millimeters per day. The mean difference between the observed and computed daily rate for that period was $0^s.015$.

Immediately following the period named, we succeeded in making the glass case air tight and during the past four years we have had practically no trouble from leakage of air. I therefore desire to present to this Society a discussion of the daily clock rates of this same clock from February 6 to June 19, 1905.

The following table gives the dates of observations, the mean pressure in the clock case, the observed daily rate, the computed rate, and the difference between the last two. The change in pressure is due to a progressive change in the temperature of the clock vault. The computed rates are obtained from the formula:

$$+ 0^{s}.00255 - 0^{s}.01247\,(B - 677^{mm}.5) - 0^{s}.000366\,(T - \text{April } 14.5)$$

deduced from a least square solution of the observed daily rates. The mean difference between the computed and the observed rates is $0^{s}.009$.

DAILY RATE OF RIEFLER SIDEREAL CLOCK NO. 70

Date		B	Obs. Rate	Comp. Rate	O — C
1905		mm.	s.	s.	s.
Feb.	6.6	681	— 0.0074	— 0.0173	+ 0.010
	10.6	681	— 0.0055	— 0.0187	+ 0.013
	14.4	681	— 0.0386	— 0.0199	— 0.019
	17.5	681	— 0.0127	— 0.0211	+ 0.008
	20.6	680.5	— 0.0317	— 0.0163	— 0 015
	24.5	680.5	— 0.0310	— 0.0178	— 0.013
Mar.	1.7	680	— 0.0144	— 0.0134	— 0.001
	6.3	679.5	— 0.0038	— 0.0089	+ 0.005
	10.5	679	+ 0.0038	— 0.0038	+ 0.008
	13.5	679	+ 0.0125	— 0.0053	+ 0.018
	18.3	678	— 0.0048	+ 0.0050	— 0.010
	25.5	678	— 0.0209	+ 0.0031	— 0.024
	28.5	678	+ 0.0199	+ 0.0019	+ 0.018
	31.5	678	+ 0.0113	+ 0.0010	+ 0.010
Apr.	2.6	677.5	+ 0.0062	+ 0.0060	0.000
	7.6	677	+ 0.0043	+ 0.0101	— 0.006
	13.5	677	+ 0.0098	+ 0.0084	+ 0.001
	17.5	677	— 0.0019	+ 0.0072	— 0.009
	20.6	677	+ 0.0118	+ 0.0058	+ 0.006
	24.5	677	+ 0.0173	+ 0.0046	+ 0.013
	27.5	677	+ 0.0146	+ 0.0031	+ 0.012
May	2.5	676.5	— 0.0079	+ 0.0074	— 0.015
	7.5	676	+ 0.0154	+ 0.0118	+ 0.004
	12.5	676	+ 0.0074	+ 0.0103	— 0.003
	16.5	676	+ 0.0058	+ 0.0091	— 0.003
	19.5	676	— 0.0014	+ 0.0077	— 0.009
	23.6	676	+ 0.0072	+ 0.0067	0.000
	25.6	675.5	+ 0.0082	+ 0.0113	— 0.003
June	1.5	675	+ 0.0137	+ 0.0154	— 0.002
	5.4	675	+ 0.0235	+ 0.0139	+ 0.010
	9.5	674.5	+ 0.0142	+ 0.0187	— 0.004
	13.4	673.5	+ 0.0403	+ 0.0300	+ 0.010
	16.4	673	+ 0.0312	+ 0.0350	— 0.004
	19.5				
					Mean 0.009

The behavior of the clock can also be shown from the clock corrections during the same period. Each clock correction depending upon ten or more time stars has been reduced to April 15.0 by the rate formula given above with the following result:

CORRECTION TO RIEFLER SIDEREAL CLOCK NO. 70, APRIL 15.0.

1905, February	6.5	— 14^{s}.33
	10.7	— 14 .29
	17.5	— 14 .30
	18.3	— 14 .29
	20.6	— 14 .28
	24.5	— 14 .34
March	10.5	— 14 .40
	13.5	— 14 .37
	15.5	— 14 .33
	25.5	— 14 .36
	27.5	— 14 .40
	28.5	— 14 .44
	29.5	— 14 .45
	30.5	— 14 .44
	31.5	— 14 .38
April	8.5	— 14 .38
	13.5	— 14 .40
	14.6	— 14 .43
	17.5	— 14 .39
	18.5	— 14 .40
	19.5	— 14 .42
	20.5	— 14 .42
	22.5	— 14 .40
	24.5	— 14 .40
	27.5	— 14 .36
May	2.5	— 14 .30
	12.5	— 14 .39
	19.5	— 14 .41
	22.4	— 14 .42
	23.5	— 14 .45
	24.5	— 14 .44
	25.5	— 14 .45
June	1.5	— 14 .44
	2.5	— 14 .42
	9.5	— 14 .42
	19.5	— 14 .44
	Mean	— 14 .39

The mean of the residuals obtained by subtracting — 14^{s}.39 from each of the above clock corrections is 0^{s}.04.

Observations were discontinued for some weeks beginning the latter part of June, so that, in order to show how well the clock correction could be predicted a new rate formula was deduced using observations from February 6 to June 1. Using this rate formula

$$+ 0^{s}.00207 - 0^{s}.01230\,(B - 677^{mm}.5) - 0^{s}.000373\,(T - \text{April } 14.5)$$

and the clock correction for April 15.0 as — 14^s.39, the predicted clock corrections for June, 1905, were obtained as given in the accompanying table:

CLOCK CORRECTIONS FOR JUNE, 1905.

Date	Sidereal Hour	Predicted Correction	Observed Correction	*O — C*
June 1.5	16.8	—14^s.04	—14^s.06	—0^s.02
2.5	16.6	14 .03	14 .01	+0 .02
3.5	16.5	14 .01	14 .04	—0 .03
8.5	16.3	13 .95	13 .91	+0 .04
9.5	16.5	13 .93	15 .90	+0 .03
13.5	14.8	13 .85	13 .85	0 .00
14.5	16.1	13 .81	13 .88	—0 .06
18.5	18.6	13 .69	13 .66	+0 .03
19.5	16.9	—13 .65	—13 .66	+0 .02
		—13 .886	—13 .882	±0 .03

ILLUMINATION OF THE REFLEX ZENITH TUBE.

BY C. L. DOOLITTLE.

As the instrument was originally constructed, the field was illuminated by a small electric lamp placed outside the tube, the light of which fell on a diagonal reflector in the axis of the instrument. The mirror was only eight inches from the micrometer threads. The result was that when the thread was not practically in the axis the reflection back and forth from the under side of the prism and the mercury surface produced a feathery appearance in the threads, making it impossible to obtain a sharp image of the same.

After considerable discussion and some experimenting the following plan was adopted: The smallest electric lamp obtainable—sometimes called a dental lamp—is placed in the axis of the instrument, six inches above the mercury surface. This is held in place by a thin strip of brass attached to the tube in such a way that it may be readily removed in case repairs or removal of the lamp are called for. The current is furnished by a dry battery, and the brightness controlled by a rheostat. It is all of home construction and gives perfect satisfaction.

ON THE CONSTANCY OF THE PERIOD OF THE VARIABLE STAR, M 5 (Libræ) No. 33.

BY E. E. BARNARD.

This is one of the Harvard cluster variables and has been under observation with the forty-inch for nearly ten years. The period derived from these observations is

$$12^{h}\,2^{m}\,7^{s}.3040 \pm 0^{s}.01781$$

The period was independently determined from normal observations at intervals of one or two years. The deviations among these values did not exceed $0^{s}.065$. Though this is approximately progressive with the time, it is not believed to be real.

An observation of the variable at its most rapid light change is subject to a probable error of about ± 1.2 minutes, which, when three or four normals are employed, is reduced to ± 0.5 minute.

The light curve shows that the star, after remaining faint for a large part of its period, rather suddenly begins to brighten and in one hour has reached maximum. It remains but a short time at maximum. The decrease for the first half hour is almost equally as rapid as the rise. It then fades slowly for the next six or eight hours to minimum. The entire light change is about 1.2 magnitudes from 15^{m} ± to 14^{m} ±.

THE PHOTOHELIOMETER.

BY CHAS. LANE POOR.

By an arrangement with Professor Frost a twenty-five-foot photographic heliometer was mounted upon the tube of the forty-inch Yerkes telescope. The lenses were two inches in aperture and were specially made for this work by Brashear. The centers of the lenses were at a fixed distance apart and this distance was so adjusted as to make the photographic images of the sun overlap. The common chord of these overlapping images is a measure of the diameter of the sun, and slight variations in the diameter produce relatively large changes in the length of the chord.

During 1907 a series of photographs were taken by Mr. Fox, but owing to bad weather the number was rather limited. They were sufficient, however, to test the value of the method and to show the general lines upon which an instrument should be built.

A POSSIBLE THIRD BODY IN THE SYSTEM OF ALGOL.

BY R. H. CURTISS.

Spectroscopic determinations of the center of mass velocity of the eclipsing stars of Algol indicate strongly that three bodies enter into this system about the center of mass of which the eclipsing pair revolves in a nearly circular orbit with a radius of not less than 89,000,000 km., a period of 1.899 years and an epoch of minimum radial velocity at the date, 1901.85.

The variations observed in the eclipse period of this star, as well as those suspected in the eccentricity, are possibly largely due to perturbations arising in such a system.

As a consequence of the orbital motion of the center of mass of the eclipsing pair a variation in the time of light minimum with a range of ten minutes and a period of 1.899 years should be shown by photometric observations.

ACHROMATIC AND APOCHROMATIC COMPARATIVE TESTS. PRELIMINARY COMMUNICATION.

BY E. D. ROE, JR.

To test them side by side, two visual telescope objectives, each of the two lens type, an achromatic and an apochromatic of 2½-inch and 2⅜-inch aperture and forty-four inches focal length, were ordered by the writer in March of Mr. Lundin, of the Alvan Clark Corporation, and of Steinheil Söhne, of Munich, respectively. Hartmann's Foucault knife-edge test as described in the *Astrophysical Journal* for May, 1908, was tried by Dr. Saunders and the writer on Mr. Lundin's objective, both visually and photographically. Color screens were used for testing chromatic aberration. Four photographic plates of the objective were secured. The objective showed high excellence under these tests. For the laboratory manipulations and appliances involved the writer is greatly indebted to his colleague, Dr. Saunders. Mounted on a 6½-inch Clark equatorial with clock work, the writer has tested the objective on double stars with splendid results. As the Steinheil objective was only recently received, the investigation is as yet unfortunately incomplete. Preliminary examination, however, raises the expectation that this objective will accomplish what its maker intended it should.

ON A QUICK VISUAL METHOD OF REDETERMINING THE FOCUS OF A LARGE VISUAL REFRACTOR WHEN USED FOR PHOTOGRAPHY WITH A COLOR-SCREEN.

BY E. E. BARNARD.

Such a large telescope as the forty-inch refractor of the Yerkes Observatory changes its focus largely from changes of temperature. But the photographic focus of such an instrument, where a color-screen is used, having once been determined, can at any time be redetermined accurately, regardless of temperature changes.

The following is the method: Find the photographic focus by the usual method of exposure on the stars. Insert in an adapter on the plate holder a high-power eyepiece with a graduated scale on the tube. With the plate holder set at the scale reading giving the best result, focus carefully with the eyepiece on a star, and record the reading on the scale of the eyepiece. At any other time, disregarding the temperature, etc., the plate holder is set at the original scale reading for the best focus, the eyepiece is inserted and the visual focus read off. If it is so many millimeters shorter or longer than the original visual reading, the plate carrier must be moved in or out by that extent. The plate will then be in the best focus for the moment. If a spider line is inserted in the eyepiece and is brought into the focal plane with the star, then any other observer can at any time determine the focus in a minute's time by bringing a star and the wires into focus and making the proper connections.

ON THE FOCAL CHANGES IN NOVA PERSEI AND ON THE FOCUS OF SOME OF THE WOLF-RAYET STARS.

BY E. E. BARNARD.

In *Astronomische Nachrichten,* No. 4232, Dr. J. Hartmann finds that the spectrum of Nova Persei changed to the nebular condition in the fall of 1902. In 1906 it had again changed and was similar to that of the Wolf-Rayet stars. Observations in the rather long interval were lacking to show when the change from the nebular spectrum had occurred.

Observations of the focus of this star were made at the Yerkes Observatory with the forty-inch telescope in 1901, 1902, and 1903. They show a change in accordance with Dr. Hartmann's spectroscopic observations.

The focus rather suddenly became nebular about the first of October, 1902, when it was a quarter of an inch longer than for a star. This lasted until the middle of November of the same year, when it slowly returned to the stellar focus, becoming stellar about February, 1903. The last of these focal measures was made September 28, 1903. The result was — 0.03 inch. This value was so small that the sign was not considered real. But for the fact that Dr. Hartmann found the Nova had finally reached a condition similar to that of the Wolf-Rayet stars, it may have a stronger significance than I supposed, for I find that those of the Wolf-Rayet stars I have examined, with the exception of one case, have their focus slightly shorter than for an ordinary star. The focal measures, therefore, verify Dr. Hartmann's results and show, furthermore, just when the change in the spectrum of the star occurred.

APPROXIMATE EPHEMERIDES OF THE FIXED STARS.

BY G. C. COMSTOCK.

When only a moderate degree of precision is required, apparent places of the fundamental stars covering a period of many years may be given in a very compendious form. Two tables of such places will be published elsewhere, one giving the coordinates of Polaris within a second of arc, for a period of twenty-five years, the other showing the apparent places of fifty equatorial stars for a similar period. The probable error of a right ascension for these clock stars is about two-tenths of a second of time.

A NEW FORM OF STELLAR PHOTOMETER.

BY E. C. PICKERING.

In this new form of stellar photometer, an artificial star is formed by allowing a small electric light, run by a storage battery, to shine through a minute hole, placed in the focus of a small auxiliary telescope. This telescope is placed at right angles to the main telescope and a piece of plane glass set at an angle of 45° reflects the artificial star into the eyepiece. A piece of opal or ground glass is placed over the hole, and the light of the artificial star is varied by moving the electric light, along the axis of the small telescope, by a known amount. The scale of the instrument accordingly depends on the law of the square of the distances, instead of on the laws of polarized light, or on the empirical law found for wedge photometers.

ON THE CHARACTER OF THE LIGHT VARIATIONS OF α HERCULIS.

BY FRANK SCHLESINGER.

This star has long been thought to be an irregular variable with a period of thirty-five to forty days and with rapid fluctuations near minimum. Frost and Adams have shown it to be a spectroscopic binary. In the spring of this year it was placed upon the observing program of the Mellon spectrograph of the Allegheny Observatory and Professor Pickering kindly agreed to have it observed simultaneously at Harvard with the photometer. Our spectrograms were measured and reduced by Mr. Baker, who deduced a period of 2.05 days for the velocity variations, very different from that assigned to the light variations. In discussing these observations with Mr. Baker it occurred to us that the star might be an Algol variable. The character of the spectrum and the form of the orbit (especially the small eccentricity) and most of the observations concerning its light, are in conformity with this idea. Mr. Wendell's observations at Harvard showed that this surmise is correct, and further proved the existence of a secondary minimum, so that the star is more properly of the β Lyrae type than of the Algol type. With the help of a diagram it may be shown how all the observed phenomena concerning this star can be explained and how the erroneous conclusions concerning the period and the fluctuations at minimum arose. The case is interesting as showing the intimate connection between photometric and spectrographic observations, the true character of the light variations being first indicated by the latter.

PHOTOGRAPHIC LIGHT-CURVE OF THE VARIABLE STAR SU CASSIOPEIAE.

BY J. A. PARKHURST.

A lantern slide was shown of the mean light curve of this star derived from eighty-six extra-focal images taken with the Zeiss six-inch doublet between October 19, 1906, and April 5, 1908. The plates were measured with a Hartmann Microphotometer and reduced with the writer's "absolute scale." The observations were best represented by a period of 1.9498 days, giving a correction of —0.0008 to Müller and Kempf's period.

The range in magnitude was found to be 0.47, from 6.52 to 6.99. Compared with Müller and Kempf's range of 0.33 (5.93 to 6.26), this gives a color intensity of 0.59 magnitude at maximum and 0.73

at minimum; the difference being similar to that found for other variables of short period. The star's spectrum is F 3 G on the Harvard classification. The radial velocity as determined from nine one-prism plates taken with the Bruce spectrograph and the forty-inch refractor, is about —7 km. per second, with but slight variation between the different plates.

This star has about the smallest range of any well-attested variable, but presents no difficulties to the extra-focal method.

ON THE IRREGULARITY OF THE PROPER MOTION OF THE STAR KRUEGER 60.

BY E. E. BARNARD.

From observations made with the forty-inch refractor of the Yerkes Observatory, the parallax of Krueger 60 was determined. The resulting value was $\pi = +0''.247 \pm 0''.010$. This agrees closely with the values determined by Dr. Schlesinger and also with that by Dr. Russell, the three values being:

Barnard	+0″.247	± 0″.010
Schlesinger	+0 .248	± 0 .009
Russell	+0 .258	± 0 .013

One of the components of Krueger 60 is a rather wide double star, found by Professor Burnham in 1890, with components of the magnitudes 9.3 and 11.0. The distance between the components is about 3¼″, and they are in rapid orbital motion. During the investigation for parallax, it was found that the proper motion of the larger star, as determined from comparisons with other stars, was slowly changing its direction, having in the past six or seven years changed about 8° or 9°, from 239° to 247°. This is undoubtedly due to the orbital motion of the two stars. It shows that the small star must have a rather large relative mass. The masses of these two stars can be accurately determined by measuring the position of *A*, with reference to near-by stars.

THE COELOSTAT TELESCOPE OF THE DOMINION OBSERVATORY.

BY J. S. PLASKETT.

This paper contains a description illustrated by lantern slides of a new installation for solar research at Ottawa. A cœlostat and secondary mirror, each of twenty inches aperture, feed a concave of 18 inches aperture and eighty feet focus . Owing to local conditions the beam from the concave has to pass under the secondary mirror to a focus in the basement of the Observatory. Notwithstanding the different and less advantageous conditions the solar definition is in general very good, much better than obtained with the refractor more suitably situated. The cœlostat is covered by a house, moving back on rails and the beam passes through a shed and a short tunnel to the focus. Both house and shed are thoroughly louvered. A grating spectroscope of the Littrow form, with a Brashear six-inch objective of twenty-three feet focus, and a Michelson plane grating ruled surface, 4¼ x 4¾ inches, arranged to rotate around its optical axis, will be used with this telescope for spectroscopic investigations of the solar rotation, sun spots, etc.

CAMERA OBJECTIVES FOR SPECTROGRAPHS.

BY J. S. PLASKETT.

This paper contains an account of tests for definition and flatness of field performed on a number of different types of lenses used in and especially made for spectrographic work. The advantages of some of the new forms of Brashear and Zeiss over those previously used is illustrated diagrammatically. For work with a single prism a new objective by Brashear with widely separated elements, both of the same material, light crown, gives the best field, while for three-prism work another single material by Zeiss, in this case of the prism material, performs most satisfactorily. Neither of these forms can be used with larger angular aperture than $f/10$. For shorter focus lenses the Zeiss Tessar seems to be most suitable. A description of the effect upon definition and flatness of field of changing the separation of the elements will be given.

THE DISTRIBUTION OF ERUPTIVE PROMINENCES ON THE SOLAR DISK.

BY PHILIP FOX.

This communication reviews a paper presented to the American Association for the Advancement of Science at the Chicago meeting on "The Detection of Eruptive Prominences on the Solar Disk" and summarizes the observations on their distribution as follows:

Spot birth is always accompanied by and generally preceded by eruptions. While the spot continues active the prominences will be present, generally following it at the edge of the penumbra. Spots beginning to decline are also accompanied with eruptions which will be seen at the ends of the bridges. In the case of complex spots where we have a large leader spot and another at the tail of the stream the eruptions follow the preceding spot and precede the following spot and are seen among the smaller spots of the stream. Eruptions are rarely seen preceding the leader spot and are as seldom found following the trailer.

The eruptions about the spot-groups are probably due in part to the interference of the whirls about the spots. Judging from the direction of motion indicated by the whirls of calcium and of the hydrogen shown on the spectroheliograms, and from the motion in some of the prominences, I find the direction of the whirls in the northern hemisphere as counter-clockwise and clockwise in the southern.

THE WORK OF THE NAUTICAL ALMANAC OFFICE.

BY MILTON UPDEGRAFF.

The American Ephemeris and Nautical Almanac is one of five similar publications, and was first issued for the year 1855 at Cambridge, Massachusetts, under the direction of Lieutenant (afterward Rear-Admiral) Chas. H. Davis, U. S. N. The American Nautical Office was established in the year 1849, was removed from Cambridge, Massachusetts to Washington, D. C., in 1866, and after occupying from time to time various quarters in the Navy Department and elsewhere in the city of Washington, was located in the main building of the new Naval Observatory in 1893. During the first forty-eight years the Almanac had four superintendents and during the remaining years six directors, the title of superintendent having been changed to director in 1893.

Professor Simon Newcomb, U. S. N., was superintendent and director for twenty years, 1877 to 1897, and during that time there were published under his direction eight volumes of the *Astronomical Papers of the American Ephemeris,* as well as the yearly volumes of the *Ephemeris* during that time. During the past eleven years the accuracy of the computations for the *Ephemeris* has been improved, a catalogue of zodiacal stars published, and orbits and ephemerides of certain new satellites of the planets computed. The next volume to be issued is that for the year 1912. It is intended hereafter to leave out the lunar distance tables, to insert the ephemerides of about three hundred additional fixed stars, and to substitute for the Struve-Peters constants the constants adopted at the conference of directors of the national ephemerides held in Paris in May, 1896. Among minor changes which are under consideration may be mentioned:

(*a*) Moon culminations given for lower as well as upper culmination.

(*b*) A more convenient arrangement of the ephemerides of the satellites of the planets.

(*c*) Ephemerides of the brightness of the planets in terms of stellar magnitude.

(*d*) Ephemerides for physical observations of the sun, moon, and planets.

The second edition of the *American Nautical Almanac* for 1909 will contain a star list and map for the use of navigators, and it is hoped later on to add certain tables and ephemerides for the convenience of surveyors and engineers.

Definite suggestions as to possible improvements in the *American Ephemeris and Nautical Almanac* from astronomers, navigators and others who make practical use of that publication, are desired, will be carefully considered and should be addressed to "The Director, Nautical Almanac, U. S. Naval Observatory, Washington, D. C."

The American Nautical Almanac Office cooperates with the British Nautical Almanac Office in certain lines of work, and is also at present cooperating with Professor Simon Newcomb, U. S. N. (retired), in his lunar researches and in a revision of the orbit of Mars. The present superintendent of the Naval Observatory, Admiral Wm. J. Barnette, is disposed to promote the cooperation of the Department of Astronomical Observations of the Naval Observatory with the Nautical Almanac Office, especially as regards the meridian work of the Observatory and the places of the fixed stars given in the *American Ephemeris.*

The distributing list for the *American Ephemeris and Nautical Almanac* has recently been enlarged by more than fifty per cent., and that for the *Astronomical Papers* has been more than doubled. The former publication is sent to libraries, though not as a rule to individuals, while the *Astronomical Papers* are widely distributed to scientific men and institutions throughout the world.

A considerable number of sets of the *Astronomical Papers*, eight quarto volumes, bound in cloth, are now available for free distribution, as also are a number of volumes and parts of volumes for the completion of sets, carriage free within the limits of the United States. There are also several hundred copies bound in cloth of an interesting and valuable book on *Astronomical Constants,* a supplement to the American Ephemeris for 1897, which will be mailed free to those who apply for it.

The publications of the Nautical Almanac Office are no longer sold by the office. On October 1, 1906, the sale of these publications was transferred to the Superintendent of Documents, Government Printing Office, Washington, D. C.

ON AN INFINITE UNIVERSE.

BY G. W. HOUGH.

This paper contains an examination of the various arguments for and against the doctrine of an infinite universe, and particularly of Chesaux's assertion that the light of an infinite number of shining bodies would cause the heavens to appear everywhere equally illuminated with the sun. The author cites various authorities, refers to investigations of his own, and in conclusion remarks that if the arguments advanced are the best that can be adduced in proof of a finite universe, the theory rests on a very weak foundation.

THE LUMINOSITY OF THE BRIGHTER LUCID STARS.

BY GEORGE C. COMSTOCK.

Parallaxes have been determined for about three-fourths of all the stars brighter than magnitude 2.5. These are here used to determine the intrinsic brightness of each such star and to derive from these a curve showing the relative frequency of occurrence of the several degrees of luminosity among the stars in question. A theoretical distribution curve for these luminosities, derived from the hypotheses with regard to stellar distribution that are commonly made, is shown to be widely divergent from the curve above found. The cause of this divergence is sought in the hypothesis upon which the theoretical curve is based and it is shown that the theoretical and observed distributions may be brought into agreement by either of the following suppositions:

(*a*) The intrinsically brightest stars are not widely distributed through space, but manifest a distinct tendency to cluster about the sun.

(*b*) There is a sensible absorption of light in its transmission through space, of such average amount that a star having a parallax of a tenth of a second appears one magnitude fainter than it would appear in the absence of absorption.

PHOTOGRAPHIC DETERMINATIONS OF STELLAR PARALLAX WITH THE YERKES REFRACTOR.

BY FRANK SCHLESINGER.

This paper is an informal report of work done with the forty-inch Yerkes telescope under the auspices of the Carnegie Institution, from 1903 to 1905. The methods and precautions adopted for making the photographs and for measuring and reducing them were described in some detail and the results exhibited for twenty-three stars.

MEASUREMENT OF STARLIGHT WITH A SELENIUM PHOTOMETER.

BY JOEL STEBBINS.

This paper presents the results of experiments on the use of selenium in stellar photometry. It is well known that the crystalline form of selenium decreases its electrical resistance when exposed to light. The method is to cast an extra-focal image of a star upon a selenium surface, and note the effect by means of a galvanometer. Using a twelve-inch telescope, it has been possible to measure first and second magnitude stars with about the same accuracy that is obtained in visual methods. Tests with brighter artificial lights give a probable error of less than one per cent. for a single measurement.

In the course of a year the sensibility of the apparatus has been increased one hundred fold, and it is hoped that further improvements in the elimination of disturbing factors will produce extremely accurate results.

SPECTROGRAPHIC OBSERVATIONS.

BY E. B. FROST.

A favorable report may be made upon the result of re-annealing by the original maker, M. Parra-Mantois, of Paris, of the three large flint prisms first made for the Bruce spectrograph and discarded on account of lack of homogeneity.

The star 46 υ Sagittarii, which has been qualitatively studied by Miss Cannon at Harvard, and was found to be spectroscopic binary by Campbell some years ago, has recently been observed, and a number of plates have been measured by Dr. D. V. Guthrie. He finds a range of velocity from + 55 km. to — 25 km. The bright lines are not conspicuous on our plates, and can be seen with certainty only on the thirteenth plate.

Observations of the fainter component of ζ Ursae Majoris (Mizar) have been continued for several months, the measures being made by Mr. Lee. A careful study by the writer has failed to bring out a regular periodicity in the radial velocity, and the indications are that more than two bodies are involved.

Mention was made of the following spectroscopic binaries:

ϕ Sagittarii ($18^h 39^m, -27° 6'$), of Orion type, which shows a large range of velocity.

β Trianguli ($2^h 4^m, +34° 31'$), Ia2, which was suspected from preliminary examination here, and established by measures of the same plates at Columbia University by Professor S. A. Mitchell.

55 Ursae Majoris ($11^h 14^m, +38° 44'$), Ia2, found by Mr. Lee; range thus far: 40 km.

ι Andromedae ($23^h 33^m, +42° 43'$), of Orion type, found by Mr. Barrett, probably of rather long period.

THE FIGURE OF THE SUN AND POSSIBLE VARIATIONS IN ITS SIZE AND SHAPE.

BY CHAS. LANE POOR.

The first part of this paper contains a résumé of the more important investigations of von Lindenau, Secchi, Auwers, Newcomb and Ambronn. In practically every case the original reductions showed periodic variations in the diameter of the sun. Auwers discussed an immense mass of meridian circle and heliometer observations and reached the conclusion that the sun is sensibly a sphere and that the observed variations are due to personal and instrumental causes. This conclusion, however, was reached only by attributing variable personal equations to the different observers.

The second part contains a retabulation and rediscussion of the heliometer observations used by Auwers and of those made by Schur and Ambronn. It is here shown that these observations indicate a periodic variation in the shape of the sun, the period being the same as that of the sun-spot cycle. The observations of Schur and Ambronn were also investigated for short period vibrations by means of the method of "Time Correlation" as developed by Newcomb. These observations indicate a semi-permanent fluctuation in the shape of the sun having a period of about twenty-eight days.

RESULTS OF PHOTOMETRIC INVESTIGATIONS.

BY F. H. SEARES.

Light curves were shown of RS Draconis, VY Cygni, RV Tauri, SU Andromedae, RS Bootis, 52.1907 Ophiuchi, and 43.1907 Draconis. All are interesting and unusual types of variation. The last four are of the so-called Antalgol type with periods ranging from ten to sixteen hours. In addition, there was presented a simple general method of determining the circular elements and relative dimensions of a binary system on the basis of the observed light variation of the Algol type. The arrangement of the method is such that the light curve corresponding to the first approximation for the elements and dimensions must be tangent to the observed curve at two points. Differential formulae can then be used for improving the agreement of the calculated and observed curves. The application of the method to a considerable number of cases can be facilitated by means of tables.

THE TEMPERATURE GRADIENTS OF THE ATMOSPHERE AND AN ATTEMPT TO ACCOUNT FOR THE UPPER INVERSION.

BY W. J. HUMPHREYS.

During the past few years many sounding balloons, equipped with registering apparatus, have been sent up from different places and under different conditions to altitudes ranging from twelve to twenty kilometers, and observations have been secured indicating a division of the explored atmosphere into the following three regions:

1. A layer some three thousand meters thick next the surface, in which the change of temperature with elevation is irregular and often locally reversed.
2. A region of fairly uniform and rapid temperature decrease with elevation extending from the top of the first layer to the high cirrus clouds.
3. The upper inversion, or the region above the cirrus clouds, where the temperature slowly increases with elevation.

The upper inversion is due primarily, but not wholly, to long wave radiation from the earth as a planet, and to which water vapor is as a black body. When the temperature of the high atmosphere is 218°C. absolute, it can be shown that the temperature of the effective radiating surface is about 260°C. absolute.

EFFECT OF INCREASING THE SLIT WIDTH ON THE ACCURACY OF RADIAL VELOCITY DETERMINATIONS.

BY J. S. PLASKETT.

Experiments at Ottawa have shown that exposure time is almost proportionally decreased with increase in slit width to about 0.075 mm. Six spectra of β Orionis were made for each of four slit widths—0.025, 0.038, 0.050, and 0.075 mm.—at three different dispersions. The accidental errors of setting, as measured by the probable errors of the velocity from a single line obtained from the six plates in each series, are only slightly increased, scarcely at all in the higher dispersion, by increase in slit width to 0.075 mm. A further discussion shows that the increase of systematic error, so far as it may be determined from the limited number of plates, is also small with high dispersion, although quite marked for a slit 0.075 mm. wide with low dispersion. These somewhat unexpected results show that for stars with single lines the slit may be much widened without much loss of accuracy and with a considerable saving in exposure time.

THE ALGOL SYSTEM, RT PERSEI.

BY R. S. DUGAN.

With a Pickering polarizing photometer with sliding achromatic prisms, a series of 14,048 settings on RT Persei was completed in February, 1908. Most of the observations were made without a recorder. The period is obtained from nineteen more or less thoroughly observed minima.

The mean curve shows a primary minimum of 1.33 magnitudes' range and a secondary of 0.16, each lasting about four and one-quarter hours. The curve between minima is not a straight line. After recovering from primary minimum the curve rises steadily until it reaches the point midway between the minima, and from that point decreases very little until the secondary minimum begins.

The residuals show a constant correction for the night, depending on the average hour angle at which the observations were made.

The eccentricity and inclination are small, the two stars are nearly of the same size, one has six times the intrinsic luminosity of the other, and the radius of the orbit is three times the radius of the stars.

OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF JANUARY 3, 1908.

BY W. W. CAMPBELL.

The paper summarized the more interesting results of the work of the Crocker Expeditions of the Lick Observatory, with lantern slide illustrations copied from the original negatives.

The corona was remarkable for the great number of long, straight and slender streamers extending in all directions. There was a conspicuous conical pencil of radiating streamers, near position angle 75°, whose vertex, if on the sun's surface, would lie within the largest sun-spot group visible on January 3.

By far the greater part of the coronal light came from the areas lying within two inches of the sun's edge.

Polarigraphic negatives showed the existence of strong polarization in the coronal light, even up to the very edge of the sun.

A spectrogram with continuously moving plate recorded the changing spectrum of the sun's edge as the edge was gradually uncovered by the moon.

The spectrum of the corona was essentially free from absorption lines. Several new coronal bright lines were discovered. The maximum of continuous spectrum of the corona was displaced toward the red from that of the solar spectrum, indicating a lower temperature in the corona than in the photosphere. The plates for the intra-mercurial planet search recorded more than three hundred stars, including some of the ninth magnitude. All were identified as well-known stars. It is felt that the Lick Observatory observations of 1901, 1905, and 1908 bring definitely to a conclusion the observational side of this problem, famous for half a century. It is not contended that no planets exist in the intramercurial region, but it is believed the undiscovered planets do not exist in sufficient numbers to provide the mass necessary to explain the anomalies in the motion of Mercury and the other minor planets.

VALUE OF THE SOLAR PARALLAX FROM PHOTOGRAPHS OF EROS TAKEN IN 1900 WITH THE CROSSLEY REFLECTOR.

BY C. D. PERRINE.

The following determination of the value of the solar parallax is based on 823 images of Eros and the images of the surrounding groups of stars contained on 281 photographs. These photographs were secured on eighteen nights from October 6 to December 24 inclusive.

The value of the solar parallax obtained is

$$8''.8054 \pm 0''.0025.$$

The measurements and reductions were made under a grant from the Carnegie Institution by Mrs. Moore and Miss Hobe.

The general results will be published in a Lick Observatory Bulletin, and a full account of the work by the Carnegie Institution.

The following additional papers were also presented at this meeting:

By W. T. CARRIGAN: An investigation of the terms in the mean longitudes of Mars and the Earth, which have the argument, $3J - 8M + 4E''$.

By MRS. FLEMING: A proposed sixth type of stellar spectra.

TENTH MEETING

The tenth annual meeting of the Astronomical and Astrophysical Society of America was held at the Yerkes Observatory, Williams Bay, Wisconsin, on Wednesday, Thursday, Friday and Saturday, August 18-21, 1909. Six general sessions were held for the reading and discussion of papers. At the close of the session on Thursday afternoon, the members were entertained at a reception given by Professor and Mrs. Frost. Friday afternoon was devoted to an excursion around Lake Geneva on private steamers kindly furnished by the owners, Messrs. Ayer, Bartlett, Mitchel, and Ryerson.

At the opening session, after welcoming the Society to Williams Bay, President Pickering referred to the loss which the Society had suffered since the last meeting through the death of two of its best-known members. Referring to them, he said, in part:

"Professor Newcomb, president of our Society for six years, always took the greatest interest in its growth and welfare. It rarely happens that a man is really distinguished in more than one department of science. We all know his preeminence in astronomy. He used to say, 'I am not a mathematician,' yet the Mathematical Society in the strongest terms proclaimed him their most eminent member.

"Our attitude should not be that of grief at his loss, but rather rejoicing that he enjoyed many years of usefulness after the age when most men's work is done; he lived to see the great works he had undertaken completed, and he is now saved the suffering which at the end rendered life a burden to him."

"Professor Hough's activity in science extended over many years. We remember, even at our last meeting, his interest in our work and plans. His observations with the Evanston telescope, at one time the largest in the world, were maintained for nearly thirty years."

President Pickering then discussed the present needs of astronomy and expressed the hope that the Society might take an active part in supplying them. One of the greatest needs is a number of small grants, not exceeding a thousand dollars each, which could be used with the sole object of securing the greatest scientific return. If made to the larger observatories, careful organization and system would permit a large amount of routine work to be secured.

If made to a small observatory, or to an amateur, the skill and experience of an expert in his own specialty might be secured, with results far beyond those which might be obtained by another astronomer, however skillful in other lines of work. The only way to supply such needs is to make them known. President Pickering invited the members of the Society to send him examples of such researches. For instance; Professor Bailey is now studying the climate of South Africa, perhaps the best in the world for an astronomical observatory, and will return shortly. He is making visual and photometric observations with a ten-inch telescope, and photographing the Milky Way with a Cook anastigmat, using long exposures. A grant of one thousand dollars would permit this work to be continued another year by his assistant, thus doubling the results obtained, with a small additional expense.

At the preceding meeting at Put-in-Bay, two committees had been appointed, one on Luminous Meteors, consisting of Professors Cleveland Abbe, W. L. Elkin, and H. A. Peck; the other on Comets, consisting of Professors George C. Comstock, Edward E. Barnard, Edward C. Pickering, and Charles D. Perrine.

The committee on Meteors presented a detailed report at Williams Bay, written by its chairman, Professor Cleveland Abbe, giving a résumé of what had previously been done toward securing photographs of meteor trails. The various methods and instruments that have been employed or proposed were critically examined from the point of view of the astronomer as well as from that of the meteorologist. The report strongly urged the establishment of a network of photographic stations about one hundred miles apart for the purpose of obtaining a tolerably complete record of all the meteors appearing within the network. Automatic instruments of as simple and inexpensive a type as practicable were recommended.

The committee on Comets reported orally through its chairman, Professor Comstock. Its attention had been given mainly to the approaching return of Halley's comet. In order that this comet may be adequately observed it will be necessary, on account of its close approach to the sun at the time of maximum brilliancy, to have stations widely distributed in longitude. To secure such stations correspondence has been had with observatories in the eastern hemisphere. The Pacific Ocean presents a wide gap in which no available station exists and the committee has assumed the task of securing funds for the establishment of a temporary station, presumably in the Hawaiian Islands. Such funds are now assured in case the circumstances of the comet's return render it desirable to send out a party. The appearances that the comet will present depend so much upon the exact date of its return to perihelion that no definite program of observation can be framed before the rediscovery of the comet. It appears, however, advisable to separate the observing program into three classes of observations, viz., photographic, photometric and spectrographic, and the preparation of a detailed program of these divisions has been entrusted, respectively, to Professors Barnard, Pickering and Frost.

The proposal to change the name of the Society to the American Astronomical Society was discussed at length on Saturday morning. It was the opinion of many of those present that the shorter name has many advantages, but fear was expressed that should the word "Astrophysical" be omitted from the name, the tendency would be to deprive the Society of that support which it now receives from those who are engaged, not in observatory work, but in allied investigations in various physical laboratories. On this account the motion to change the name was lost.

During the meeting an informal discussion took place concerning the advisability of passing a resolution designed to counteract such impressions as might have been created by recent newspaper statements respecting the possibility of establishing communication with other planets, particularly with Mars. The members present were unanimous in believing that such attempts would be useless and deprecated the use of any funds for such purpose, but were not inclined to dignify by formal action the absurd accounts which had recently appeared in the papers. The Society finally referred the matter to a committee, consisting of Messrs. Edward C. Pickering, George C. Comstock, and Edwin B. Frost, with authority to make such statement to the Associated Press as seemed to them best. The statement issued by the Committee was as follows:

"As the public through the misrepresentation of the views of certain astronomers has formed the impression that communication with other planets is at present possible, the Astronomical and Astrophysical Society of America desires to express its belief that all such proposals fall outside the range of sober contemporary science."

At the final session on Saturday morning, officers were elected as follows:

President	Edward C. Pickering
First Vice-President	George C. Comstock
Second Vice-President	W. W. Campbell
Treasurer	C. L. Doolittle
Councilors for two years	W. S. Eichelberger Edwin B. Frost

Dr. Frank Schlesinger was elected Editor for the meeting.

The last formal action to be taken by the Society before its adjournment was the unanimous adoption of the following

RESOLUTION.

"The Astronomical and Astrophysical Society of America, assembled at its tenth annual session, records its great regret at the death of its first president, Professor Simon Newcomb. Deeply interested in the cooperation and mutual influence of scientific men, Professor Newcomb was conspicuous in the organization and early progress of the Society, and was a dominant factor in determining its relation to contemporary astronomy. His enthusiasm for the science and his wide knowledge of its many branches made his presence and participation in the meetings of the Society a perennial inspiration to its members.

"Professor Newcomb's own achievements in exact and theoretical astronomy have already become classics in the history of the subject, and will constitute his permanent memorial. The record of a long and active scientific career is closed with the fulfilment of many of his most cherished ideas, and we deeply regret that he was not longer spared for the further development of those subjects to which he had largely contributed.

"The Society records its profound respect for the departed member and directs its secretary to transmit a copy of these resolutions to his bereaved family."

ABSTRACTS OF PAPERS

SOME RESULTS WITH A SELENIUM PHOTOMETER.

BY JOEL STEBBINS.

This paper is a report of progress in the method of using selenium for the electrical measurement of starlight. It has been found that the best results are obtained by keeping the selenium at a constant low temperature in an ice pack. During the past summer, the accuracy of the method has been so increased that it is now possible to measure first-magnitude stars with a probable error of less than one one-hundredth of a magnitude.

PRECAUTIONS NECESSARY IN PHOTOGRAPHIC PHOTOMETRY.

BY J. A. PARKHURST.

The results of experiments with stellar and laboratory plates, both focal and extra-focal, were shown by curves thrown on the screen; and the possible errors in stellar magnitude arising from each source were indicated. (1) Comparison of developers, gradation very different. (2) Time of development, possible error exceeding one magnitude. (3) Temperature of development, error nearly one magnitude for range of ten degrees Fahrenheit. (4) Effect of sky fog, possible error of half a magnitude for fog of 0.03 of a density unit. (5) Temperature of exposure, difference of 0.1 magnitude for plates at + 17° and — 2° C. (6) Reduction formulæ for disk diameters of focal images. Error of half a magnitude possible if logarithm of diameter is used in the formula instead of square root of diameter. (7) Atmospheric absorption. Difference of 0.17 magnitude between the visual and photographic absorption at 60° zenith distance. (8) Curvature of commercial plates. Error negligible for focal images but might amount to half a magnitude for extra-focal images. (9) Corrections for distance from axis for plates taken seven millimeters from the focus of the Zeiss doublet, amounts to 0.33 magnitude at three degrees from the axis. (10) Correction for distance from axis of focal plates might differ by 0.8 magnitude between summer and winter temperatures. (11) Correction for color of stars of solar type is one magnitude.

STANDARD PHOTOGRAPHIC MAGNITUDES.

BY HENRIETTA S. LEAVITT.

Observations for the purpose of determining the absolute photographic magnitudes of a sequence of forty-seven stars near the North Pole have recently been in progress, as described in Harvard College Observatory Circular 150. Sequences of forty stars in the Pleiades and twenty-six stars in Præsepe have also been measured, and the results compared with those obtained for the polar stars.

About one hundred and fifty plates were used, taken with eight telescopes. Several methods were employed for determining absolute magnitudes, independent of the visual scale, but all may be grouped in the three following classes:

1. Photographs were taken, diminishing the light by means of

screens, or by reducing the aperture of the telescope, and superposing a second exposure of the same length with full light. A similar effect was obtained by attaching an auxiliary prism of very small angle to the object glass; this deflected a part of the light, forming secondary images of the brighter stars.

2. The light was divided by interposing two thin plates of Iceland spar. The positions of the four images of each star furnished the means of determining the relative amount of light in each image.

3. Photographs were taken, having several exposures on the Pole Star, and on the star to be observed, the images being out of focus by varying amounts.

The results obtained by these radically different methods are accordant with each other in the great majority of cases. They also agree closely with the Harvard photometric scale as far as the magnitude 13.2, after allowing for difference of color. We apparently have a satisfactory working basis for determining the magnitudes of stars in all parts of the sky, on an approximately correct scale.

In the discussion that followed Mr. Stebbins' and Miss Leavitt's papers, Messrs. Parkhurst and Humphreys called attention to the large error which might sometimes be incurred by assuming that the absorption of our atmosphere is the same in different azimuths. Professor Pickering remarked that it was the practice to guard against this source of error at Harvard by establishing an arbitrary limit for the residuals obtained with the meridian photometer and similar instruments, and rejecting all observations in which this limit was exceeded.

A VARIABLE STAR WHOSE LIGHT CURVE RESEMBLES THAT OF R CORONÆ BOREALIS.

BY ANNIE J. CANNON.

This star, like R Coronæ Borealis and RY Sagittarii, has long periods of normal brightness followed by sudden fluctuations of large range at irregular intervals. Its position for 1900 is R. A., $5^h 43^m 12^s$; Decl., $+ 19° 02'.0$. It follows the Durchmusterung star $+ 19°$ 1081 about 3^s and is south $0'.2$.

THE PIVOTS OF THE NINE-INCH TRANSIT CIRCLE OF THE U. S. NAVAL OBSERVATORY.

BY F. B. LITTELL.

This paper, which was read by Professor Eichelberger in the author's absence, gave the results of several determinations of these errors. The investigation is valuable not only for its application to the work with this instrument, but is of general interest on account of the experience with various methods for determining inequalities of pivots.

THE ALGOL SYSTEM, Z DRACONIS.

BY R. S. DUGAN.

The material for this paper consists in 18,384 settings made with the Pickering sliding prism polarizing photometer, attached to the 23-inch equatorial. Considerably more than half the settings were read and recorded by an assistant. Eleven minima were observed in whole or in part. These minima, together with those observed and published in detail by Graff, gave a graphical determination of new elements. The star at its faintest phase was seldom more than just visible. Under these conditions there was no evidence of variability in the depth of minimum. The mean curve shows a nearly symmetrical primary minimum consisting in a drop of 2.55 magnitudes, and also a secondary minimum of 0.065 magnitudes. Each lasts about six hours. After recovering from primary minimum, the curve keeps on rising slowly for some time, and the beginning and ending of secondary minimum are at a higher level than those of primary minimum. This would indicate ellipticity and reflection. The average surface intensity of one star is 18 times that of the other, and the radius of the fainter lies between 0.98 and 1.86 times that of the brighter. The radius of the orbit is from 3.5 to 5 times the radius of the brighter star.

THE PROBLEM OF THREE BODIES FROM THE STANDPOINT OF SPECTROSCOPY.

BY KURT LAVES.

With the present accuracy in the determination of velocities in the line of sight the problem of three bodies begins to assume importance in this department of astronomy. The paper dealt with that phase of the subject that is analogous to the lunar problem.

The perturbation by the "sun" is broken up into three components, $P, T, S,$ along the radius vector, perpendicular to it and perpendicular to the plane of the orbit, respectively. Calling z' the velocity in the line of sight of the disturbed body, we have

$$dz'/dt = -P \sin \theta + T \cos \theta$$

in which θ is the longitude from the ascending node. P and T may be expressed as functions of θ and when t is also expressed in terms of the same quantity we obtain an equation of the form $z' = F(\theta)$. A comparison with the observed velocity curve leads to a determination of the inequalities involved. The approximation has been carried as far as the second power of the parameter involved.

THE DETERMINATION OF THE MOON'S THEORETICAL SPECTROSCOPIC VELOCITY.

BY KURT LAVES.

It was shown that the four quantities V_1, V_2, V_3, V_4, in Campbell's notation, can be calculated by means of tables computed on the basis of the elliptic polar coordinates of the earth and the moon.

$$V = K \, . \, e \, . \sin \theta \qquad (1)$$

will give both V_1 and V_2. V_1 can not exceed 0.50 km. per second, and V_2 is always less than 0.04 km. As the diurnal change in V_1 and V_2 is at most 0.012 km. we may use approximate values of the longitudes of the sun and the moon.

$$V_3 + V_4 = V_2 \cos E + K_2 \, (1 + e_2 \cos \theta_2) \sin E \cos \beta_2; \qquad (2)$$

this formula is easily proved with the aid of the hodographic circle. The index 2 refers to the moon. For $K_2 \, (1 + e_2 \cos \theta_2)$ tables may be constructed with the argument θ_2, the true anomaly of the moon. The angle E, which is nearly the difference between the longitudes of the sun and the moon, is computed thus:

$$\tan p_2 = \tan \beta_2 \operatorname{cosec} (\lambda_2 - \lambda) \text{ and } \sin E = \sin \beta_2 \operatorname{cosec} p_2. \qquad (3)$$

Tables based on (3) are being computed for various values of β_2. They will be applicable to the planets as well. As the *Nautical Almanac* is planning to discontinue the computation of E the tables here described should be of considerable value to the astrophysicist.

THE EFFECT OF FAULTY COLLIMATION OF THE CORRECTING LENS ON THE STAR IMAGE.

BY J. S. PLASKETT.

The field of the correcting lens used with visual objectives for photographing star spectra is very limited. A slight displacement from the axis disperses the star image, causes a perceptible difference, transversely, in the position of the images due to light of different wave-lengths. It was shown that even the flexure of the telescope is sufficient to produce this effect. The importance of correct adjustment and of compensating for flexure in the effect on exposure time and on the accuracy of radial velocity measurements was pointed out.

THE WIDTH OF SLIT GIVING MAXIMUM ACCURACY.

BY J. S. PLASKETT.

This paper was a continuation and conclusion of one with a similar title presented at the last meeting. It gave results for other instruments of the relative errors of measurement of early type spectra at various slit widths. It was shown that more accordant and accurate values are obtained at a width of about 0.05 mm. than at either narrower or wider slits. Consequently considerable saving of exposure time over that usually given is possible. The bearing of these results on the proportions of the optical parts in spectrographs was also discussed.

THE PHOTOGRAPHIC DOUBLET OF THE DOMINION OBSERVATORY.

BY R. M. MOTHERWELL.

The images produced by the Brashear eight-inch doublet were surrounded by a halo and a series of tests by the Hartmann method showed this to be due to spherical aberration. On the lens being refigured, by the kindness of the Brashear Company, the halo disappeared and it now gives small and sharply defined images with a widely extended field. Diagrams were shown of the aberration at the normal separation of the front elements, at increased separations, as well as after refiguring.

ON THE PHOTOGRAPHS OF COMET c 1908 (MOREHOUSE).

BY E. E. BARNARD.

About 350 photographs of this comet were obtained with the three lenses of the Bruce telescope of the Yerkes Observatory. These pictures cover essentially all the more remarkable phenomena of the comet during its visibility in these latitudes, including the extraordinary outbursts or changes that occurred on September 30 and October 15, 1908. The last photograph was obtained here on December 13, 1908, when the comet was close to the horizon. The photograph of December 11 was one of the most remarkable of the entire set. The paper also deals briefly with the possible cause of these extraordinary changes in the tail of the comet.

ON SOME EXPERIMENTS IN PHOTOGRAPHING ENLARGED IMAGES OF THE PLANETS, DIRECT WITH THE FORTY-INCH TELESCOPE.

BY E. E. BARNARD.

Experiments have recently been made, with improved facilities, in photographing directly enlarged images of the planets with the 40-inch telescope. Some of the photographs of Jupiter which show the belts well, stand a subsequent enlargement of upwards of two or three inches. Better results are hoped for by the use of a new screen by Mr. Wallace. The results so far show that it is now mainly a matter of favorable definition to secure valuable photographs.

ON THE PROPER MOTION OF SOME OF THE SMALL STARS IN THE DENSE CLUSTER M 92 HERCULIS.

BY E. E. BARNARD.

The visual and photographic measures of the great star clusters show that but little motion exists in any of the small stars composing them. In M 92 Herculis motion is shown in several of the smaller stars, amounting in two cases to as much as 5″ a century. These two stars are of magnitude 13.3 and 14. Motion also seems certain in at least three other stars of between magnitude 14 and 15. The next fifty years ought to give us some idea of the relative motion of many of the stars in this cluster. These motions have been brought to light, in this cluster, perhaps because a closer investigation has been made for that purpose than in the case of other clusters.

LACK OF SPECTROSCOPIC EVIDENCE OF A DISPERSION OF LIGHT IN SPACE.

BY EDWIN B. FROST.

Examination of plates of spectroscopic binaries, taken with the Bruce spectrograph of the Yerkes Observatory, does not give evidence of a difference of radial velocity for different wave-lengths. The star β Cephei, having a period of $4^h\ 34^m$, would appear especially suitable in this connection. A large range of wave-lengths is obtained for this star only on one-prism plates, and on these any such effect would probably be masked by the accidental errors of measurement. Statistics were read for the star μ Orionis, which has a short period, 0.77 day. The spectrum has sharp lines, and many plates have been obtained with three prisms. These show no systematic difference of velocity at different wave-lengths. Mention was made of work successfully commenced with one prism in the red end of the spectrum. While intended for a different purpose, these plates would be available also for a wider range of wave-length in this connection.

VERTICAL TEMPERATURE GRADIENTS IN THE ATMOSPHERE AS DETERMINED BY SEASON AND BY TYPES OF WEATHER.

BY W. J. HUMPHREYS.

A large number of sounding-balloon records were grouped according to season and height of the barometer. The results show that while the difference between summer and winter temperatures is most pronounced at the surface of the earth, it is still decided—about half as great—at the highest elevations thus far reached, and that this difference remains essentially constant above an elevation of about ten kilometers, or in the isothermal region. The seasonal effect therefore extends presumably through the entire atmosphere. On grouping into separate curves the summer gradients obtained during high and low barometric conditions, it is seen that the high barometer, or clear weather conditions, insure higher temperatures than does the low barometer at the surface of the earth and up to near the isothermal region where the conditions are just the reverse; that is, colder in clear than in cloudy weather. Barometer changes have the same effect on the temperature gradients both in winter and summer, except at the surface of the earth. Here the temperature is the lowest in winter during clear weather, or high barometer, and the highest under the same conditions during summer. The low barometer gives exactly opposite results. All these phenomena can be explained as the results of radiation and absorption, especially as modified by condensation and varying amounts of water vapor in the atmosphere.

A PROPOSED METHOD OF STUDYING SOLAR RADIATION AT GREAT ALTITUDES.

BY W. J. HUMPHREYS.

The fact that the solar spectrum is limited to wave-lengths greater than 2,900 Angström units, makes it desirable to determine whether this limitation is due to atmospheric or to solar absorption. High mountain observations have not definitely settled the question and therefore observations at much greater elevations would be desirable. It is proposed to send small automatic spectrographs to great altitudes with sounding balloons. A suitable spectrograph for this purpose was described with a method for securing proper illumination of the slit and exposure at any predetermined altitude.

PLANETARY MAGNETISM OF THE SUN.

BY W. J. HUMPHREYS.

Assuming an ionization and electric separation in the sun's atmosphere sufficient to account for the magnetic condition that Hale has found in the spots, and assuming unit magnetic permeability, or that which obtains for all known substances at high temperatures, it is easy to compute the magnetic field of the rotating sun as a whole. This would be sufficient to produce a magnetic separation, in the case of the more sensitive lines of only about one one-thousandth of an Angström unit, an amount too small for certain detection. An absence of measurable polar effects must therefore not be taken to be in conflict with the cyclonic theory of the origin of magnetism in the spots.

NEW PLANS FOR TABULATING THE MOON'S LONGITUDE.

BY E. W. BROWN.

These plans having already been put into more or less definite shape, the paper contained an account of those parts of them which presented unusual features. The main difficulty consists in tabulating the very numerous small terms chiefly due to planetary action. The great majority of these can by special devices be put into tables. It is hoped that a machine which has just passed through the experimental stage will enable the computer to obtain the sum of the other small terms with great rapidity for half-daily intervals. An outline was given of the general principles that were used as guides for forming tables, the interests of the ephemeris computer being placed before those of the single place computer whenever they were at variance. A detailed account of the methods will be published within a few months.

A PROPOSED DESIGN FOR AN OBJECTIVE PRISM SPECTROGRAPH FOR THE DETERMINATION OF RADIAL VELOCITIES.

BY FRANK SCHLESINGER.

It is proposed to employ two photographic doublets of say six inches aperture and of nearly equal focal lengths. Before each is to be placed a prism of the same aperture, the refracting edge of the one being turned toward the north and of the other toward the south. Plate glass is to be employed for the sensitive plates and one of them is to be turned with the glass side toward the objective. One of the objections to the use of an objective prism in quantitative work is the effect of changes of temperature upon the dispersion of the prisms. It is proposed to obviate this difficulty by surrounding the entire spectrograph with a temperature case supplied with an automatic temperature control, the light from the stars being admitted to the objective by means of two sheets of plane-parallel glass. The plates are to be measured by superimposing them and obtaining the distance between corresponding lines in the two spectra of each star. These distances will be affected by the radial velocity and will therefore enable us to compute the latter. After an investigation into the various distortions that the spectrograph would involve, and of the sources of error to which the measures would be liable, it was concluded that with such a spectrograph radial velocities of faint stars could be determined with a probable error not exceeding ten kilometers for each pair of plates.

IMPROVEMENTS IN THE OBSERVATORY AT ANN ARBOR.

BY W. J. HUSSEY.

In addition to minor matters these include the following:

1. The establishment of an Observatory Instrument Shop, equipped for the construction and repair of instruments.
2. The construction of a new driving clock for the six-inch refractor, and providing a camera for use in connection with this instrument.
3. The installation of sets of seismographs of the Bosch-Omori and Wiechert types.
4. The re-mounting of the twelve-inch refractor and the addition of a new filar micrometer for it.
5. The construction of a 37½-inch reflecting telescope, equatorially mounted, arranged for use in Newtonian and Cassegrain form. This instrument is designed for photographic and spectroscopic work. A single-prism spectrograph for radial velocity determinations has been obtained for use in connection with it.
6. The erection of an addition to the Observatory, providing class rooms, offices, photographic rooms, clock room, etc. This addition includes a forty-foot dome for the new reflecting telescope.

ON DIFFERENTIAL FLEXURE IN THE SINGLE-PRISM SPECTROGRAPH.

BY R. H. CURTISS.

Serious differential flexure effects have been detected in the conventional cantilever type of spectrograph, which is especially liable to this source of error when used in connection with the equatorial telescope. The flexure in the meridian being known, the operation of this effect with changing hour angle is easily determined for any part of the sky and may be shown to enter with a large percentage of its maximum value in exposures of ordinary length on stars in unfavorable positions.

In the case of the new single-prism spectrograph of the Observatory of the University of Michigan, the flexure has been effectually eliminated by the method of support. A homogeneous brass box carrying the slit head, optical parts, and plate holder is supported at three points, two of which were fixed in the original design. The third was placed at a point determined by actual trial such that the flexure displacement of spectral lines caused by the change of position of the spectrograph is eliminated.

THE FOCAL CURVES OF THE SINGLE-MATERIAL CAMERA DOUBLET OF THE SINGLE-PRISM SPECTROGRAPH OF THE DETROIT OBSERVATORY.

BY R. H. CURTISS.

This paper dealt with a recent investigation of the focal curves from λ 3900 to λ 6000 of the new camera lens mentioned in the title. The collimator is an Isokumat of 27.5 inches focus and 1.4 inches aperture. The camera lens has a focus of sixteen inches. Nine different combinations of collimator and prism settings were tried covering all cases that might be advantageous. It was found that the deviation from straightness of the focal curves was practically the same in all cases over a distance of thirty-four millimeters. But for the portion of the curve corresponding to the interval λ 4000 to λ 5900 the deviations were least for minimum deviation settings in the neighborhood of λ 4400. It was found that the entire region from λ 3900 to λ 6000 could be photographed in sharp focus upon one negative.

THE NEW SPECTROGRAPH MEASURING ENGINE OF THE DETROIT OBSERVATORY.

BY R. H. CURTISS.

This engine was constructed from designs by Dr. Curtiss based upon his experience with instruments of the Zeiss, Toepfer and Gaertner types. The principal features are: a sector for inclining the engine at any desired angle; a long clock spring for taking up the back-lash of the screw; a reversible secondary plate carriage; a motion of rotation of the microscope around an axis parallel to the screw; the use of an interrupted reticle and a removable reticle holder to carry glass reticles of any type. The screw of the engine was made at Ann Arbor, in the Obseratory Shop and seems to possess a remarkable accuracy.

SOLAR SPECTROSCOPIC OBSERVATIONS.

BY PHILIP FOX.

Results in these lines of work were presented: (1) Spectrograms of a dark calcium flocculus that had a high velocity. (2) A brief report on the work undertaken by Dr. Abetti and the author on the sun-spot spectrum. The photographs were obtained with an 18-foot Littrow spectrograph used with an horizontal telescope of sixty feet focal length. The investigation covers the region from λ 3900 to λ 6800 and includes about eight thousand altered lines. (3) A preliminary report concerning a comparative study of the spectra of the details of the photospheric granulation.

THE USE OF QUARTZ FIBERS FOR MICROMETER WIRES.

BY PHILIP FOX.

Spider-threads, while excellent in many ways, have two disadvantages: they are affected by humidity and they are too coarse. It is a difficult matter to find spider threads whose diameters do not exceed the resolving power of the telescope. The author has made some experiments with quartz fibers furnished by Professor Nichols. There was no difficulty in finding and mounting fibers that were one-third of the usual diameter of spider threads. They are very smooth and do not readily retain dust particles, they are easily illuminated and are not affected by changes in humidity. One fiber has been in use for more than a year.

In the discussion that followed this paper attention was called to the fact that owing to the non-elastic qualities of the fiber there was a tendency for it to work loose from the mounting, under the temperature conditions that usually prevail at a telescope.

SOME DYNAMICAL CONSIDERATIONS ON GLOBULAR STAR CLUSTERS.

BY F. R. MOULTON.

The assumption on which this paper was based is that the dimensions, masses and relative velocities in the globular clusters are such that they maintain essentially constant dimensions. Consequently, if this assumption is sound, when two of the three classes of data are furnished by observations, the third, *e. g.*, the masses, is given by the equational relation which is developed.

If π is the parallax of the cluster, D the diameter of the cluster in the same units, N the number of stars in it, then ρ, the average distance between adjacent stars, is

$$\rho = \frac{D}{\pi \sqrt[3]{N}}$$

If $N = 5{,}000, D = 30'$, $\pi = 0''.01$, which is the mean parallax of fifth magnitude stars according to Kapteyn's formula, we have $\rho = 10{,}500$ astronomical units.

An important question in the discussion is whether a star passing through the cluster has many close approaches to other stars, and whether it may be prevented from leaving the cluster by the general gravitative control of the whole group of stars. If R is the radius of the cluster in astronomical units, the probability, P, that a star passing through the cluster will pass within r astronomical units of at least one other star is

$$P = \frac{3}{2}\left[\frac{r}{R}\right]^2 N.$$

With $r = 10$ and the data assumed above, we have $P = 1/43{,}000$. Hence near approaches in such a system are extremely rare.

The period of revolution of a star in a star cluster of approximately homogeneous star distribution, is

$$T = 2\pi R^3/k\sqrt{M},$$

where M is the total mass. Supposing $M = 5{,}000$ times the sun's mass and the other data as above, we find $T = 89 \times 10^{12}$ years.

The greatest velocity is

$$V = k\sqrt{M}/\sqrt{R}$$

at the center of the cluster. With the data used above, $V = 1.04$ astronomical units per year; or, in angular measure, as a maximum, $0''.01$ per year. The apparent angular velocity varies with the three-halves power of the parallax. Consequently if the large value taken above is actually ten times too great, the greatest apparent angular velocity is only $0''.0003$ per year. If these numerical assumptions be regarded as reasonable, then sensible relative motions of permanent members of star clusters are not to be expected until the observations extend over some decades.

ACHROMATIC AND APOCHROMATIC COMPARATIVE TESTS—SECOND COMMUNICATION.

BY E. D. ROE, JR.

This paper presented the final results of the testing of two objectives, which was outlined a year ago in a preliminary communication before the Society. The two objectives, two-lens type achromatic and apochromatic telescope objectives of approximately the same aperture and focal length, by Mr. Lundin and Steinheil Söhne, respectively, were tested visually on double stars, and in the laboratory. The photographic knife edge test was applied to both objectives with satisfactory results, while the color curves of the two lenses were ascertained by measurements on extra- and intra-focal spectrograms. The paper will appear in *Archiv für Optik.* (Berlin).

REPORT OF PROGRESS ON THE RADIAL VELOCITY PROGRAM OF THE LICK OBSERVATORY.

BY W. W. CAMPBELL.

The programs of observation for the Mills spectrograph attached to the 36-inch equatorial, and for the D. O. Mills expedition to the southern hemisphere (Santiago, Chile) have aimed to secure at least four spectrograms of every star down to the 5.0 visual magnitude, with 3-prism dispersion if possible, and of somewhat fainter stars, especially in the southern hemisphere, with 2-prism dispersion. Up to June 1, 1909, 3-prism spectrograms of 882 stars had been obtained at Mt. Hamilton; 200 of these, whose spectra contain broad and poorly defined lines, have been rejected from the main program for observation later with lower dispersion. Excepting these, the northern observing program is essentially complete for the good summer months; and if next winter, and especially next spring, have average weather conditions, the program should be nearly complete throughout the twenty-four hours of right ascension, by June 1, 1910. The D. O. Mills expeditions, under Astronomers Wright and Curtis, successively, have observed altogether 530 stars brighter than 5.01 visual magnitude and about 150 stars fainter than 5.00 magnitude, or 680 stars in all. Correcting for those stars observed at both Mt. Hamilton and Santiago, the total number of stars whose spectra have been photographed is 1,368. The original Mills spectrograph was succeeded in May, 1903, by a new Mills spectrograph. All the spectrograms obtained with the original spectrograph, and about three-fourths of those obtained with the new spectrograph, have been measured and reduced definitively, and are being rapidly prepared for publication. During the first period of the D. O. Mills expedition, in charge of Astronomer Wright, covering two years of observation, spectrograms of about 200 stars were secured. Those containing lines suitable for accurate measurement numbered 148, and four plates, on the average, were obtained for each of these. The results, including all the text, are entirely ready for publication in volume form. Of these 148 stars, 29, or one in five, have been found to have variable velocities. Of the plates secured during the second period of the D. O. Mills expedition, under Astronomer Curtis, about one-third have been measured and reduced definitively by Dr. Curtis and his assistant, Mr. Paddock, while carrying on the work of observing. The remainder have been measured approximately—that is, utilizing only a few of the available lines. It should be said that only a small proportion of the spectroscopic binaries discovered at Mount Hamilton and in Chile have been investigated. To do this would require several years of observing, measurement and computation.

THE LICK OBSERVATORY DOUBLE-STAR SURVEY—A REPORT OF PROGRESS.

BY R. G. AITKEN.

The program for this survey as originally planned contemplated the examination of every star to the magnitude 9.0 in the Bonn Durchmusterung from the north pole to declination 22° south, with the object of securing data for a statistical study of double stars. Since 1905, when Professor Hussey left the observatory, the work has been carried on by the author alone. It should be completed in two years' time, provided that the observing conditions between December and June are reasonably good. At present about 85 per cent. of the area has been examined; 3,375 close double stars have been added to those previously known and of these 1,327 are to Professor Hussey's credit. One star in eighteen of those examined has proved to be a double with a separation under 5″. It appears that double stars with a separation under 2″ are far more numerous than those between 2″ and 5″. The discussion of the material thus far collected is under way, but definitive results will not be forthcoming until the survey has been extended to the south pole. It is hoped that an expedition suitably equipped to carry out this program may be sent to South America by the Lick Observatory immediately upon the conclusion of the present survey.

SPECTROGRAPHIC AND PHOTOGRAPHIC OBSERVATIONS OF COMET c 1908 (Morehouse).

BY HEBER D. CURTIS.

Between the dates February 23 and March 23, 1909, one slit spectrogram and seventeen objective-prism spectrograms were secured at the observatory of the D. O. Mills expedition. With the slit spectrograph it was found possible to obtain only the strongest of the pairs of lines of unknown origin which characterized this comet. The wave-lengths of this pair as derived from the slit spectrogram are λ 4254.2 and λ 4275.4.

The following are the wave-lengths as derived from the objective-prism plates: λ 3914.1, λ 4002.1, λ 4021.3, λ 4254.0, (λ 4276.0), λ 4526.0 ±, λ 4545.9, λ4570.2, λ 4690.7, λ 4716.3. Collecting the differences for the three strongest pairs of lines, λ 4002-21, λ 4254-76, λ 4546-70, together with the corresponding angles at the comet between the radius vector and the line connecting the comet with the earth, we have:

Observer	Date	$\Delta\lambda_1$	$\Delta\lambda_2$	$\Delta\lambda_3$	Angle
Deslandres and Bernard	1908 Oct. 14	20	23	20±	39°.9
Deslandres and Bosler	Nov. 1	19.7	21.6	20.0	46 .3
Campbell and Albrecht	Nov. 28	19.6	20.7	20.8	37 .2
Curtis	1909 Feb. 25	18.5	22.0	24.5	39 .7
Curtis	Mar. 21	19.4	22.5	23.8	35 .6

The objections to interpreting the doubling of these lines as a Doppler-Fizeau effect have already been stated by Campbell and Albrecht (*cf. Lick Observatory Bulletin,* No. 147). Assuming the actual velocities along the tail or transverse to the tail to have been the same when Deslandres and Bosler observed on November 1 and when the author observed on March 21, the mean of the intervals for the three principal pairs of lines should have been about four tenth-meters greater, or less, respectively, on March 21 than on November 1, whereas the observed intervals were not quite one tenth-meter greater on the latter date.

The various spectral images are replicas of the tail, as shown by the direct photographs taken at the same dates, as far as can be made out on the small scale of the plates. In this respect the plate of March 20 is of especial interest. The direct photograph on this night shows a marked curve in the tail about half a degree from the head, a curve which is duplicated in each of the spectral images.

Twenty-eight direct photographs of the comet were also made during this period, the majority of them with a 6⅛ inch portrait lens; many of these plates show interesting evidences of the extraordinary activity which characterized this comet both before and after perihelion.

THREE STARS OF GREAT RADIAL VELOCITY.

BY HEBER D. CURTIS.

A number of stars with proper motions of 1″.0 per year or greater have been investigated with the spectrographs of the D. O. Mills expedition to the southern hemisphere, and in the course of this work three stars have been found with radial velocities of unusual magnitude. Of these the most interesting is the star Cordoba Zones $5^h 243$ ($\alpha = 5^h\ 7^m.4$, $\delta = -44^\circ\ 56'$) whose proper motion of 8.7 seconds of arc per year is the greatest thus far observed. Its magnitude is 9.2, and its photographic magnitude about 10.5, so that a satisfactoy plate was secured only by prolonging the exposure time to twenty-nine hours on four consecutive nights. The mean of the two plates shows that the star is receding from the sun at a rate of 242 km. per second. Using the Cape value of the parallax of this star, 0″.312, with Kapteyn's values for the proper motion in right ascension and declination, and eliminating the motion of the solar system in accordance with Campbell's value, the resulting space velocity of this star is about 261 km. per second, directed toward a point whose coordinates are $\alpha = 122^\circ$, $\delta = -60^\circ$. This enormous space velocity seems to be exceeded only by the star 1830 Groombridge, which is traveling at a rate of about 278 km. per second toward an apex in $\alpha = 250^\circ$, $\delta = -52^\circ$. From five plates a velocity of recession of 100 km. per second was found for the star Lacaille 2957, and a velocity of approach of 132 km. per second in the case of the star Lacaille 8362, derived from three plates.

THIRTEEN STARS HAVING VARIABLE RADIAL VELOCITIES.

BY HEBER D. CURTIS.

This paper gave a list of thirteen new spectroscopic binaries discovered during the past two years in the course of the work of the D. O. Mills expedition to the southern hemisphere. Eight of the number were discovered by Dr. Curtis, and five by Mr. George F. Paddock. In two cases the spectra of both components of the system are visible.

NOTE ON THE APPARENT WAVE-LENGTHS OF LINES IN THE DIFFERENT SPECTRAL TYPES AND IN CERTAIN VARIABLE STARS.

BY SEBASTIAN ALBRECHT.

In 1906 the author made an investigation of the individual spectrum lines in certain spectrograms, with a view of determining whether there is a shift of any of the lines which is progressive from spectral type to type. A preliminary list of lines which undergo such a change, as indicated by the radial velocities obtained from them, was published in November, 1906. This investigation has been continued intermittently during the last two years, and a number of additional lines have been found whose positions also change progressively.

In the paper referred to, a comparison was made with Mr. Adams's list of sun-spot lines (*Astrophysical Journal,* Vol. XXIV). The principal result of the comparison was the strong indication that the physical conditions in the stars as we pass from the F to the Mb type vary roughly in the same direction as from the sun to the sun-spots. The results for the additional lines are in harmony with the above conclusion.

In his first paper the author expressed the opinion that for variable stars of large light changes similar changes of apparent wave-lengths of line might be found, corresponding to changes in spectral type from maximum to minimum. Measures of the available spectrograms of the fourth class variables η Aquilæ and 1 Carinæ were tabulated according to phase of light variation and some lines in the case of each star were found to show a variation dependent upon the phase of the light curve. In general, the direction of variation is such as to indicate a later spectral type at minimum than at maximum, though the variation does not in each case take place in the same part of the light curve. The change in the spectrum of the variable star is probably such that the spectrum always has some characteristics of more than one spectral type.

UNPUBLISHED WORK OF THE HARVARD OBSERVATORY.

BY EDWARD C. PICKERING.

Discussion of the Revised Harvard Photometry, *H. A.*, 64, 4, pp. 56; ready for distribution.

Observations on J. D. 3182 with the Four-inch Meridian Photometer, *H. A.*, 64, 5, pp. 12; ready for printing.

Magnitudes of Components of Double Stars, *H. A.*, 64, 6, pp. 34; in type.

A discussion of the Eclipses of Jupiter's Satellites, 1878-1903, by Ralph A. Sampson, *H. A.*, 52, 2, pp. 190; in type.

Durchmusterung Zones Observed with 12-inch Meridian Photometer, 190 pages; in type.

Maxima and Minima of Variable Stars of Long Period, 130 pages; in type.

Photometric Measurements made with the East Equatorial, by Oliver C. Wendell, pp. 56; in type.

Photographic Magnitudes of Seventy-two Bright Stars, Photographic Observations of Occultations, Eclipses of Jupiter's Satellites, Transformation of Prismatic to Normal Spectra, Miscellaneous, by Edward S. King; nearly ready for printing.

Statistical Investigations of Planetary Orbits, by W. H. Pickering; nearly ready for printing.

The Zone of Stars, in declination —9° 50′ to —14° 10′, observed by Professor Searle with the eight-inch meridian circle, is now nearly completed. It will occupy three volumes of the *Harvard Annals.* It will be sent to the printer this autumn, unless unforeseen delays arise.

THE PHOTOGRAPHIC SEARCH FOR PLANET O.

BY W. H. PICKERING.

The search for this planet was prosecuted on plates taken by the Rev. Joel H. Metcalf with his 12-inch doublet. Two plates of each region were taken at intervals of a few days apart. A positive was printed from one of these, and the other negative superposed upon it. It was expected to detect the planet by its motion during the interval elapsed. The planet has not as yet been found. This may be due to one or more of three causes: (*a*) The planet may be unexpectedly faint, or reddish in color. Its computed magnitude is

13.5. (*b*) The orbit may be highly eccentric, the computation being based on an approximately circular orbit. (*c*) The orbit may be highly inclined to the ecliptic, and the planet at present situated far from its node. For various reasons the first two causes are not thought sufficiently effective to interfere with the discovery of the planet. We might, by analogy, compare planet *O* on account of its relative size and position with regard to the other planets, to the sixth or seventh satellite of Jupiter. The inclinations of the orbits of these two bodies are 28° and 26°, respectively. The region already covered in the photographic search extends along the ecliptic for 25°, and reaches to a maximum distance of 10° to the north and south of it. It is expected therefore to make an examination of the higher latitudes next year. The number of stars already examined in the search is estimated at about 300,000.

THE SPECTRUM OF A METEOR.

BY WILLIAMINA P. FLEMING.

On August 14, 1909, while examining a shipment of plates recently received from Arequipa the spectrum of a meteor was found on a photograph taken with the Bruce 24-inch telescope on May 18, 1909. This must have been an unusually bright object, since its trail is very intense, consisting of twenty-three bright lines or bands. As the photograph has so recently been received at Cambridge no study of the spectrum has as yet been attempted.

GRADUATION ERRORS OF THE CIRCLES OF THE SIX-INCH TRANSIT CIRCLE OF THE U. S. NAVAL OBSERVATORY.

BY J. C. HAMMOND.

This consisted of a description of the methods and results of a thorough examination of the circles that is still in progress. The circles were graduated by the Warner and Swasey Company, of Cleveland, and seem to be quite as accurate as those of the best foreign makers. The examination brought to light a periodic error that repeated itself in every ten minutes of arc. This was traced to a slight eccentricity of a ratchet-wheel and has been corrected for circles subsequently graduated with this engine.

CLOCK VAULT OF THE U. S. NAVAL OBSERVATORY.

BY EDGAR TILLYER.

In this paper, which was read by Professor Updegraff in the absence of the author, Mr. Tillyer described the devices adopted for maintaining constant temperature in the vault in which are mounted three Riefler clocks.

ON THE CONSTRUCTION OF ASTRONOMICAL PHOTOGRAPHIC OBJECTIVES AT THE U. S. NAVAL OBSERVATORY.

BY GEORGE H. PETERS.

Mr. Peters first described the various attempts that had been made to install a photographic instrument at the observatory with the use of material already at hand, the most noteworthy of these being the reassembling of the parts of the old mounting of the 26-inch equatorial to serve as a mounting for various cameras. Mr. Peters has now undertaken the construction of two 10-inch objectives of about 110-inch focus. These are of the type in which three lenses are employed with large separations. The curves were computed by Mr. Tillyer and the grinding is being done with a machine constructed in the observatory shop.

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